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## A QUALITATIVE ANALYSIS OF TICKLING: ITS RELATION TO CUTANEOUS AND ORGANIC SENSATION<sup>1</sup>

By ELSIE MURRAY, PH. D.

Assistant in Psychology at Vassar College; late Fellow in Psychology  
at Cornell University

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<sup>1</sup>From the Psychological Laboratory of Cornell University.

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The following study was undertaken in the interests of certain problems in the analysis and classification of organic sensation. It was our belief that the thorough examination of some complex lying, so to say, on the border line between the cutaneous and the organic might open up a pathway to the more detailed investigation of the latter. For such preliminary exploration the use of the phenomenon of ticklishness or tickling seemed obviously appropriate.

While the primary object of experimentation in the work which follows was the analysis of the immediate sensory contents of tickle, the possibility that the uniqueness of the tickle-consciousness may lie merely in the bodily reaction which it excites was not lost sight of. The questions which we set ourselves to answer were as follows. Are the ticklish sensations aroused by a light touch to be classed as cutaneous or organic?<sup>1</sup> Do they represent pressure,<sup>2</sup> a new pain quality,<sup>3</sup> a complex of

<sup>1</sup> By organic is here meant a sensation mediated by non-cutaneous nerve endings, hence presumably unique in quality.

<sup>2</sup> Cf. A. Goldscheider, Die spezifische Energie der Gefühlsnerven der Haut, 1884; F. Kiesow, *Zeitschrift für Psych. und Phys. der Sinnesorgane*, XXXIII, 429-430; and O. Külpe, *Outlines of Psychology*, 1895, 148.

<sup>3</sup> S. Alrutz, *Undersökingar öfner smärtsinnet*, *Upsala Univ. Arskrift*, 1901.

tactual and muscular impressions,<sup>1</sup> circulatory sensations reflexly aroused,<sup>2</sup> or pressure and pain in combination? Lastly, if it is non-organic in origin, upon what conditions or peculiarities of content does the strikingly subjective character of the tickle-consciousness depend?

In the solution of this problem our interest was not confined to the determination of the independence or identity of the points of maximal sensitivity for tickle and those for any other sensation, pain or pressure. The emphasis was rather upon the introspective estimation of the qualitative likeness or unlikeness of tickle and certain simple variations and complications of pain, pressure, and the like. Full experiential knowledge of the cutaneous qualities, under varying intensive, spatial, and temporal conditions, was thus acquired. The methodological value of this material for the further study of organic sensations is readily apparent. For the task of isolating, disintegrating, and classifying such organic complexes as hunger, thirst, fatigue, and the bodily accompaniments of the emotions, certain factors in the introspective outfit of the observer are (as a brief experience proves) indispensable. The first is the possession of a tolerably stable set of standard elements, drawn from the sense departments that are most germane (tactual and kinæsthetic). The second is a rough descriptive catalogue or working knowledge of the apparent modifications of quality<sup>3</sup> which any simple element may undergo, *i. e.*, of the simplest laws of fusion and complication.

The close dependence of progress in organic analysis upon such preliminary knowledge may be illustrated as follows. One of the first questions which arises in the study of organic sensation hinges upon the significance of the distinction between "dull" and "sharp" or "bright." Does the division of organic sensation into two classes, which seems roughly feasible, represent an ultimate sensory distinction? Are there two qualities, the one invariably correlated with plain muscle activity, the other possibly with circulatory changes in the internal tissues? Or are dullness and sharpness modifications

<sup>1</sup> W. Wundt, *Human and Animal Psychology*; C. S. Sherrington, in Schäfer's *Textbook of Physiology*, II, 976.

<sup>2</sup> Suggested by M. von Frey: *Berichte d. math.-phys. Classe d. kön. säch. Gesellschaft*, 1894, 192.

<sup>3</sup> The observations recorded in this article, along with a series of introspections on kinæsthetic sensations, tingling, heat and cold pain, neuralgic pain, etc., kept by the writer for a number of months, have resulted in distrust of many verbal distinctions commonly accepted as qualitative and ultimate. The apparent qualitative diversity, reducible to the metamorphoses of a single quality under varied conditions of massing and duplication, is hardly less considerable than the diversity attainable through the varied spatial disposition and intensive modification of a single visual quality, as gray.

of a single original quality, brought about by alterations in spatial extent, intensity, or the effectiveness of attention? Again, the question arises of the affinity on the one hand to pain, on the other to contact, of certain bright or sharp sensations felt internally in the "thrill" of pleasure or excitement, in the tingling of a limb which has been asleep, and in other contexts. In both cases, experimental variation of the conditions in the sphere of cutaneous sensation, and an introspective knowledge of cutaneous pain at low intensities, offer a short cut in the direction of the probabilities which the experimenter cannot afford to neglect. Thirdly, in the study of organic and semi-organic complexes the possibility of the deceptiveness of certain judgments, such as that of localization in the third dimension (*i. e.*, lack of projection beyond the surface of the body), arises. Familiarity with the underlying structural pattern and with the reliability of such judgments in the sphere of cutaneous sensation is the necessary preliminary for any adequate examination of this question.

#### SECTION A. PRESSURE AND PRESSURE SPOTS

This section of the work was designed as a preliminary to the study of tickling, and was devoted primarily to the determination of von Frey pressure spots and the development of a definite notion of the characteristic response of a single pressure organ to punctiform stimulation. It was our original intention to identify a few responsive pressure spots, to test them for tickle with a series of graduated intensities, to map a given area for points of maximal sensitivity to tickle and pressure respectively, to compare the results, and so to weigh the probabilities in favor of identifying tickle with the modality of pressure. For the carrying out of the first steps in this programme the method of von Frey and Kiesow, of mapping with minimal stimuli, was obviously inappropriate, since the liminal sensations thus utilized are difficult of analysis to the untrained observer, and may well indicate the locality of tickle rather than of pressure organs. We therefore decided to select, for initial exploration, a stimulus intensity capable of evoking the classical 'granular' pressure quality in its greatest perfection and isolation. This method also is open to objection, in the burden which it lays upon introspection; but apart from its immediate value, it promised precisely the training in the discrimination and description of slight tactal differences which was essential to our general purpose.

At the outset of this procedure, however, technical difficulties and introspective complexities began to make their appearance. Since the latter seemed frequently at odds with accepted qualitative distinctions, we felt obliged to postpone the later steps of our investigation while a series of experiments under vary-

ing hypotheses as to the number and affinities of cutaneous qualities was undertaken. When preliminary experimentation with tickle made further apparent the need of a minuter analysis than was anywhere accessible of the sensations resulting from mechanical stimulation of the skin, this line of the investigation was extended beyond our original intention. The modification which our conception of the elementary tactful sensation underwent, in consequence, will be described later.

The majority of the experiments cited in this article were carried out in the Cornell Laboratory in the year 1906-7. Observers were Professor I. M. Bentley, Mr. L. R. Geissler, assistant in psychology, and two advanced students in the department of psychology, Miss M. C. West and Mr. R. Sailor. Professor T. A. Hunter and a junior student, Miss Rosemon, also contributed a number of results. The writer herself occasionally took the part of observer, and a few of the final results are based solely on her introspections, no other observers being accessible at the time.

#### PRELIMINARY EXPERIMENTATION

*I. Search for the Adequate Stimulus of Goldscheider's Granular Pressure Sensation.* In view of the rare occurrence of isolated pressure sensations, and the lack of training of most of the observers in pressure problems, recourse was had to Goldscheider's classical description of the pressure quality.<sup>1</sup> Trial was then made in the vicinity of the larger hair-bulbs on the arm or the back of the hand for a stimulus implement which should give rise to the most perfect fac-simile of the sensation thus described.

To our surprise and disappointment, stimulus hairs of medium diameter (such as were used by von Frey and Kiesow) were effective rather in calling out a bright, sharp, superficial sensation, at its higher intensities tending to merge into pain, than in reproducing the compacted deeper-lying sensation, sometimes sharp, sometimes dull, which gradually became the observer's ideal of an isolated pressure. Hairs of small calibre gave only an elusive tickle, bright contact, or a fine stinging pain, immediate or belated. Bristles, glass hairs, and points of carbon, wood, and cork, of various lengths, diameters, and degrees of sharpness were also tested. The blunter gave everywhere practically the same undifferentiated, dull, diffuse sensations, tending to pass imperceptibly into a subcutaneous ache. The sharper and finer, if sufficiently stout, gave now and then a well-defined pressure, too often, however, marred by an accompanying point of pain which, in its weaker intensities, blended subtly with the pressure proper, to the confusion of the

<sup>1</sup> Die specifische Energie der Gefühlsnerven der Haut, Gesammelte Abhandlungen, i, 1898, 77-8.

observer.<sup>1</sup> Wooden points of a certain sharpness and glass hairs with a welded end gave most uniformly results which accorded with the definition.<sup>2</sup> It was desirable, however, for our further purposes to select an implement the intensity of which could be easily graduated. Choice was finally made of a horse-hair of about 0.2 mm. diameter, fitted into an aesthesiometer tube so as to present an adjustable length of 2-6 cm., with corresponding stimulation values ranging from 26 to 2.5 mg/mm (von Frey's tension units), and giving rise in its upper range of intensities to a fair pressure and a minimum of pain. In a few cases a bristle of about 0.33 mm. diameter, 3 cm. long, with a tension value of 36 mg/mm. was employed, the optimal stimulus varying somewhat with the observer and the area investigated.

*II. Determination and Verification of Pressure Spots.* An area 5 cm. square, situated on the back of the hand or on the volar surface of the arm and near the elbow, was selected for exploration. The locality chosen varied slightly from observer to observer, in every case, however, commanding itself by the relative fewness of the hairs and the infrequency of the distracting after-pain or itch which frequently attends stimulation. The hairs on the area chosen (about 2 to 5) were mapped and shaved, and the area explored bit by bit; the observer, who by this time had acquired considerable experience with punctiform cutaneous stimuli, indicated the points at which the resulting sensation squared with his pre-established notion of pressure. The effort was made to abstract as far as possible from the influence of mere sharpness or pain in the formation of these judgments, and the observer employed as criterion the memory-images of pressure developed in the course of previous experimentation.

The distinctive features of this sensation, while practically identical for the different observers, were variously phrased, as "not sharp, but well-defined or well massed;" "a solid core of pressure under the skin;" "muscular feel, deep, lumped-up." The points chosen usually lay to the windward of a hair, as remarked by von Frey.

<sup>1</sup> These two facts (apparently overlooked or minimized by most observers), the existence of bright but fairly painless pain sensations, and the overlapping of pain and pressure stimulus ranges, reveal the untrustworthiness of the customary laboratory direction to map for pressure by means of the clearest and most distinct sensations. The presence of a weak but hardly distinguishable pain must frequently exercise an influence on such judgments.

<sup>2</sup> Later results, harmonizing even more exactly with the definition, were obtained by the device of a quickened thrust of the stimulus hair, or by the application of a pin-point (over the more insensitive pressure bulbs). This latter method seems, on careful reading, to be the approved one for the production of the typical pressure sensation in the writings both of Goldscheider and of von Frey.

Evidence of the stability of the points thus determined was very halting. In spite of the greatest care in marking the skin, and in guarding against errors due to slipping, the point of attack yielding the best granular pressure on one day had often shifted considerably on the next. Repeated stimulation of the point during the same observation period, for the purposes of verification, often resulted in the substitution of a piercing pain for pressure. Finally, in re-examining the area with weakened stimulus intensities (at the expense, of course, of the genuine "granular pressure" quality), it was frequently noted either that the points of greatest sensitivity under these altered conditions did not coincide with the marked pressure spots, or that points of equally vivid sensibility were discoverable in the intermediate areas. The quality of these intermediate points, under the conditions, was bright but not painful.

*III. Electrical Stimulation of Pressure Spots.* Weak faradisation of the region above the hair follicle was then resorted to, as possibly more efficient than mechanical stimulation for the exact determination of the position of the pressure spot. To our surprise, the first sensations to emerge with increase of current were not those of pain, as the observations of von Frey had led us to expect, but certain shadowy, quivery shreds of sensation, which with increase of the current became a sharp tremolo or tingle, totally foreign to the specific pressure quality adopted as the standard in our observations. With continued increase of current, these pricking, tingling sensations seemed to fuse into a sharp tearing pain, which, however, rapidly died away. We sought in vain for anything corresponding in our estimation to the throbbing pressure sensation reported by von Frey as the characteristic occurrence. The only suggestion of a pressure response reported by the observer was an occasional dull areal pressure of considerable extent, usually referred by the observer to the contraction of the muscle fibres of the skin, and not intermittent but steady, lasting even after the removal of the electrode; or a very deep dragging pressure, seemingly below the pain zone and hardly distinguishable from ache. The term 'pressure' was here, however, obviously applied in its popular objective sense, not at all in the restricted technical significance given it in this article. A similar criticism applies to the throbbing pressure which was finally obtained from the gums. It was obvious, then, either that electricity could not be employed in mapping, or that we had somehow gone astray in our selection of the typical pressure sensation.

*IV. Comparison of Pressure Sensations from Different Areas.* Examination was then made of isolated pressure sensations from different regions, in order to discover whether the sense

contents which we had adopted was really typical or was merely an artifact, dependent on the composition of the tissues, etc., in the regions stimulated. Pressure sensations from the palm, the gums, the lips, and the hair-bulbs of the calf of the leg were examined and compared with those from the arm.

Striking differences immediately became manifest. From neither the palms, the gums, nor the lips could a truly granular, "lumped-up," "compacted" quality be obtained. From the mucous membrane of the gums only a bright sensation, verging on pain, and fading quickly into a dull diffuse after-sensation, with nothing of the true granular or knotty character about it, was obtainable. From the palm (where prolonged observation is greatly hindered by the secondary pain or itch sensation accumulating as the result of stimulation for pressure) a 'thrilly,' 'fizzly,' 'boiling' or 'swarming' feeling was the prominent feature. With a slightly different set of the attention, however,—probably on an infinitesimally later phase of the sensation,—a duller, deeper *pressure* would be remarked, and the "thrilly" aspect sensed only as a bright fringe or halo, half ticklish. Rarely, an intermediate stage was caught, when the thrill and the duller core seemed to fuse into something nearer the granular pressure of the back of the hand. This strengthened an interpretation which had already suggested itself, that the so-called 'granular pressure' is a complex, consisting possibly in a fusion of one bright tactual sensation with a duller component, excited by the impact of the hair-bulb or touch corpuscle on deeper-lying nerve-endings.

In case of the lips, also, the sensation is 'tingly' rather than granular and compact. From the pressure spots over the hair bulbs on the calf, which were tested with a sharp pin-point (Goldscheider's method), results intermediate between those from the palm and those from the arm were obtained. The sensation possessed body, tridimensionality, a dullish substrate, but the sharpness aspect, which too often verged on the painful in the case of the arm area, was here milder and in some cases apparently complex, as if a tiny group of bright points were incompletely fused with a certain dull component into something closely approximating the typical granular pressure.

*V. Serial Stimulation of a Pressure Spot.* In order to examine the sensation differences correlated with different stimulus intensities, and the possible appearance of tickle at the lower limit of the scale, the marked spots over the hair bulbs were stimulated with a series of intensities ranging from 2.5 to 26 mg/mm. Four different series, varying in length from 4 to 15 steps, were given, ascending and descending alternately. At each step in the series the observer was required to give a qualitative judgment.

In the results of all four observers, four apparently qualitative differences made their appearance in succession in the series.<sup>1</sup> Each of these— tickle, contact or brightness, pressure and pain— was correlated with a fairly well defined range of intensities in the stimulus scale. These ranges were, however, somewhat overlapping, and indeed the qualities themselves sometimes appeared in conjunction. Further, the sequence of the contact, pain, and pressure qualities varied somewhat according to the length and direction of the series, a fact apparently correlated with the operation of fatigue.<sup>2</sup> The intensity ranges corresponding with the four qualitative phases were as follows: tickle, 2.5 to 8.5 mg/mm; contact, 5 to 11 (rarely to 22); pressure 8.5 to 26; pain, 25 to 26.

Typical series for three of the observers run as follows:

B.	26 mg/mm.	Pressure, sometimes ending in a painful prick.
	20	Pressure with brightness in it.
	13	Lively pressure.
	8.5	Brightness core.
	5	Diffuse.
	2.5	Tickle.
G.	26	Pressure.
	20	Well-defined sharp contact with pressure below.
	13	As before.
	8.5	Well-defined sharp contact.
	5	Tickle or contact, pointed.
	2.5	Doubtful. Creeping tickle?
S.	26	Pressure and pain later.
	20	Pressure and contact.

<sup>1</sup> The observers were especially cautioned to base their judgments on the immediate sense-experience, and not on subsequent inference or objective reference. The translation of factual sensation into terms of the stimulus is, however, so ingrained and instantaneous that purely qualitative analysis is greatly impeded. Immediate visualization of the stimulus or of the denting of the skin was the rule; sometimes an interpretation in kinæsthetic or verbal terms was substituted. It is perfectly possible, then, that the descriptive distinctions maintained represent neither disparate sensation qualities mediated by different endings, nor diverse phases within a single qualitative continuum, but verbal associations merely, conditioned primarily by different degrees of intensity and diverse *Gestaltqualitäten*, secondarily by the visual sharpness or bluntness of the imaged stimulus. The intensity explanation seems, however, negligible. Introspection goes to show that, with weak mechanical stimulation, qualitative differentiation of contents is prior to the perception of intensity differences. On the other hand, the dependence of these descriptive distinctions upon unanalyzed complexities of content—due *e. g.*, to the spread of stimulation to adjacent endings, to slight temporal or intensive irregularities, and the like—is a question which demands attention with reference especially to granular pressure and tickle.

<sup>2</sup> Thus contact or sharpness may appear in a descending series only in connection with the first (most intensive) stimulus, instead of extending over its customary range of intensities.

13	Contact.
8.5	Contact.
5	Contact, bright, punctiform, definite.
2.5	Tickle or contact.

The terms in which the different observers phrased their differentiation of the four qualities were as follows. The isolated pressure quality, as obtained from the arm or the back of the hand, is deep, compact, definite, massive or "massed," dull or muscular, easily passing into an ache. "Contact,"<sup>1</sup> on the other hand, is superficial, sometimes punctiform, sometimes areal, bright or sharp, shading into tickle at the one end of the intensity scale, into fine sharp pain at the other. More extrinsic points of opposition are found in the temporal aspects of the two. Contact rises abruptly and fades quickly, while, pressure is more lasting, dying away slowly into a long dull after-image. Again, as to the degree of projection, of objective reference or localization in the two cases: contact is referred to the surface, with visualization either of the skin area or of the stimulus; pressure, on the other hand, is not projected to the surface, is usually sensed "below the skin" with less precise visualization and localization, but with a certain spatial character of its own, apparently conditioned in most cases by a very vague visualization. Pressure is thus conceived of as having weight, body, bulk, a "lumped-up" or "tridimensional" character, as over against the bidimensional nature of contact or brightness.<sup>2</sup>

A word must be said further on the use of the term 'dull,' and on the possibility that the so-called granular pressure sensation represents not the elementary tactal quality but a complex. Three of the observers showed a tendency to fall back upon the popular use of the term pressure; they associated it with the dull massive sensation correlated with the impinging of any extended solid object on a fleshy portion of the body. Granular pressure, it was discovered, meant in many cases a definite, rounded-off portion of this pressure, welded more or less perceptibly with brightness (contact). A further evidence of the significance attached to the attribute of dullness appears in the statement that pressure "feels as if the skin were dead," in the greater ease of recognition of pressure spots, when the bright superficial quality had been "fatigued out," as the observer put it; and in the liability to confuse the

<sup>1</sup> More exactly the sensation correlated with moderate intensities; called 'contact' by two of the observers only.

<sup>2</sup> The question as to how far these criteria represent associative factors, correlated merely with degrees of intensity or diffusion of stimulation, will be met later.

light diffuse surface sensation from intermediate areas with weak stimulation of an over-worked pressure organ.—

A brief description of tickle and its relation to contact may here be inserted, though a fuller account will be given in the section on tickle proper. The sensations arising at the lower limit of the stimulus scale were fugitive, vague, elusive as color sensation on the periphery of the retina, and were classed by the observer as 'doubtful,' 'faint tickle' or 'contact'. The distinction between tickle and contact at this level is, in the opinion of the observer, one of objective reference and definiteness of localization rather than of quality pure and simple. Two forms of tickle are distinguishable, in the case of punctiform stimulation; neither bore any obvious resemblance to granular pressure. The first occurs on the palms or lips; it is quick, sharp, lively, akin to pain, thrill-like or vibratory, fairly well localized, but with considerable irradiation and after-image. The second, occurring in the vicinity of hair-bulbs on the arm, hand, etc., is faint (but hardly dull), fine (but hardly distinct), on the surface or just below (but very hazily localized), brief (but usually long enough to display a faint flickering).

#### SUMMARY OF RESULTS

The significant points in these initial experiments may be summarized under four heads:

1. The difficulty of securing an isolated granular pressure without pain.
2. The difficulty in the precise localization and verification of pressure spots; and the apparent existence in the intermediate areas of other spots of approximately equal sensitivity.
3. The inability to reproduce the granular pressure sensation by electrical stimulation of verified spots.
4. The differentiation of pressure and contact (or sharpness) in the introspective results, and the similarity between the latter (rather than the former) quality and tickle.

The theoretical bearing of these facts, and their congruity with histological and physiological data must now be examined.

#### THEORETICAL: THE HISTOLOGICAL SUBSTRATE

1. *Original Assumptions.* Our procedure as originally planned was based on the tacit acceptance of certain points in the von Frey doctrine of cutaneous elements.<sup>1</sup> First, the sensitivity of the skin to pressure is, strictly speaking, punctiform. Each point of greatest sensitivity (*Tastpunkt*) corresponds to a

<sup>1</sup> As set forth in his "Untersuchungen ü. d. Sinnesfunctionen d. menschlichen Haut," *Abhandlungen d. kgl. sächs. Gesellschaft*, 40, 1897. The results published earlier, in the *Berichte*, differ considerably in certain important details.

single buried end-organ, either a Meissner corpuscle or a hair follicle with its wreath of nerve endings. The cases in which, on hairy areas, the number of pressure spots exceeds the number of hair bulbs is negligible. The characteristic sensation resulting from the isolated stimulation of a pressure organ is the granular pressure of Goldscheider. Pressure and contact (*Berührung*) are merely different phases of the same quality, the latter fainter and more fleeting. The characteristic pressure sensation may be produced by electrical stimulation of the pressure point, with direct or induced current. Lastly, the sense departments of pressure and of pain are disparate, each possessing its own nerve endings and its own intensive limens.

The task of harmonizing the introspective intricacies of our own observations with this position was an increasingly perplexing one. The most persistent points of discrepancy in our results were as follows. First, pressure and contact (or brightness), as produced by different stimulus strengths on the same spot, differ in quality rather than in intensity proper. Secondly, contact or brightness spots occur in the areas between the pressure spots, and yield sensations which differ from those of the pressure spot (at the same stimulus intensity) in body and complexity, not in definiteness and clearness. Thirdly, the electrical stimulation of pressure spots evokes a kaleidoscopic group of sensations which are individually more akin to the contact or brightness quality than to granular pressure. The appearance of pain in connection with pressure spot stimulation is not in itself incongruous with the von Frey separation of pain and pressure, since good evidence has been brought of the double innervation of the hair follicle; but the existence of a range of weak pain intensities, accompanying pressure spot stimulations and closely imitating contact or brightness sensations, is a fact demanding closer scrutiny.

It seemed probable that differences in method and outlook, in the strictness with which qualitative criteria were applied, lay at the root of these discrepancies. For example, the granular sensation produced by mechanical stimulation of the hair-bulb undoubtedly represents an unique sensory contents. Suppose that, without inquiry into its simplicity, this sense-contents is accepted as the standard, that the limiting value for noticeable stimulation of such points is determined, and that the pressure spots of any given area are mapped upon this basis. Then, even if outlying points existed which, along with an equally vivid sensibility, possessed slightly higher limens, it is obvious that by reducing the trial stimulus-intensity these might be eliminated, and the number be narrowed down to one to a hair-bulb. Further, since the granular pressure sensation belongs uniquely to the spots thus selected, their less distinctive

phases of sensation might easily be overlooked or assimilated to the "granular" contents; and the unlikeness of the equally unique response of the spot to electrical stimulation, together with the existence of the intermediate points of sensitivity, might be dismissed as irrelevant anomalies. The procedure thus outlined is, on the whole, the most straightforward and consistent from the point of view of the physiologist who is in search of definite points of pressure sensitivity. In the absence, however, of corroboratory histological evidence, we are free to consider whether some other interpretation of the facts may not do greater justice to the psychology of the question. The difficulty of reconciling our observations on tickle with the doctrine of granular pressure gave us an added motive toward some revision of our original hypothesis.

2. *Tentative.* At this point of our inquiry the facts seemed to indicate some such schema of the qualitative categories as the following:

a. Pressure and 'contact-brightness' or touch are disparate qualities. Blunt and sharp represent primarily qualitative rather than perceptual differences. The dullness which characterizes the former is not the product of the welding together of a number of punctiform sensations at low intensities, but is an unique sensation quality. It finds a familiar representative in the 'pressure' of everyday speech, the sensation (*minus* its kinæsthetic accompaniments) of a heavy body resting against the skin. The contact quality, on the other hand, is more akin to tickle, and is above all bright, vivid, definite.<sup>1</sup>

b. Contact-brightness and pressure are mediated by different histological elements, the former by fibres ending around the hair follicle and in the more superficial layers of the skin, and very susceptible to fatigue; the latter arising from deeper-lying elements, free endings in the vessels, Pacini corpuscles, muscle spindles or the like. The greater efficacy of pressure over the hair-bulb in the production of the latter sensation is probably due to the concentration of the mechanical effect through the grinding down of the comparatively solid follicle upon the underlying endings. The more superficial set of endings furnishes the sensory data for precise localization and cognizance of the finer detail of tactual impressions, angularity,

<sup>1</sup>The distinction here formulated seems closely related to Meissner's differentiation of touch from pressure (*cf.* his *Beiträge zur Anatomie und Physiologie der Haut*, 1853); a distinction which it has been customary to dismiss as a confusion of cutaneous and kinæsthetic factors, the passive and the active elements of touch. A similar distinction has been made by Bronson in his discussion of tickle and the persistence in man of a primitive contact-sense mediated by the epidermal fibrillæ (*cf.* *The Medical Record*, XXVIII, 425).

figure, etc., on the analogy of the now discredited "Ortsinn" of the earlier physiologists and psychologists. The other set of endings may be taken to represent the sense which, in conjunction with ache or pain, figures in the passive estimation of differences of weight.<sup>1</sup> Evidence of the histological independence of these two senses may be found in the observations of Head.<sup>2</sup>

c. The so-called granular pressure is not itself an element, but is a complex of deeper pressure and contact as above defined.<sup>3</sup> Hence arises the difficulty of exact reproduction by superficial faradisation of the skin. Hence also comes the disagreement of investigators as to the occurrence of pressure on certain areas where the appropriate conditions for the coupling of these two components of granular pressure are absent, *e. g.*, the cornea.

d. Lastly, it is possible that "contact-brightness" and pain represent not distinct qualities, but shades, so to speak, within the same continuum. The fact that pain arises from intensive electrical stimulation of the hair bulbs might be considered a point in favor of this hypothesis; but the occurrence, under various forms of stimulation, of ambiguous stabbing sensations which introspectively are equally akin to contact and pain furnishes a stronger argument.

The possibility of harmonizing the findings of von Frey with this position is perhaps less remote than might at first glance be imagined. It is not unlikely that von Frey in his investigation of *Druck* or *Tast* has usually in mind the bright, quick quality which we have differentiated from pressure, and that the granular pressure of Goldscheider has significance in his

<sup>1</sup>Weber's law has been demonstrated only for comparatively high stimulus intensities (100-300 grammes and above). The lower intensities (100 gr. and below) which, according to our hypothesis, would be mediated by the superficial contact endings require different stimulus progressions, and the sensations themselves are subject to a rate of fatigue too rapid for their satisfactory use in difference determinations. Cf. H. Griffing, *On Sensations of Pressure and Impact*, *Psych. Rev. Monograph Supplements*, I, 1895, 30 and 42.

<sup>2</sup>Cf. his discussion of the disassociation of deep and superficial pressure following injury to the radial and external cutaneous nerves, *Brain*, 1905, Part 2, 99. While stimulation with cotton wool, or a camel's hair brush is unappreciated, a light touch with the point of a pencil, the head of a pin, or the tip of the finger is immediately sensed.

<sup>3</sup>The difficulty of isolating cutaneous sensation from that of the underlying tissues is commonly conceded. The question at issue here is somewhat different, inasmuch as it concerns the complexity, not of the whole sense-contents attending mechanical stimulation, but of the granular sensation in itself. At this point of our analysis, we were inclined to regard the deeper component as the unique factor differentiating granular pressure from the sensation of intermediate points.

system rather as an unique pressure-spot experience than as the ultimate qualitative unit. His classification of paraesthesiae, tingling, and electrically excited sensations with pressure or *Tastempfindungen* seems, indeed, to point to this conclusion. Again, with regard to the differentiation of dull and sharp, von Frey himself in a recent statement<sup>1</sup> has recognized the distinction between touch and deep pressure as valid, conceding the conclusiveness of Head's evidence, and suggesting the muscle spindles, or the Pacini or Golgi-Mazzoni corpuscles as the terminal organs for the latter quality. Lastly, as to the number and distribution of touch points and the status of the intermediate points yielding only bright (not granular) sensations, the original *Berichte* reports would seem to agree fairly well with our position. The reduction of the number of spots to the hair, in the *Abhandlungen* and in Kiesow's later work, is the result of a more or less arbitrary lowering of the test intensity (from 4 to 0.5 mg/mm) in different cases.

So far, then, our proposed revision has found no essential contradiction in the observations of von Frey. It remained only to submit the schema to the test of experimentation. The modification which the hypothesis underwent in consequence will be discussed later.

#### FURTHER INVESTIGATIONS AND RÉSUMÉ OF RESULTS.

If pressure and touch actually represent not different intensity phases of the same quality but discrete modalities, experimentation should be able to show that the two vary independently, are affected differently by fatigue and drugs, possess different limens, and probably differential features in the conditions of their adequate stimulation in general. Even if their terminal organs are frequently associated, some cases ought to be found in which the points of greatest sensitivity are not identical; and, to eliminate the explanation of the quality differences in terms of intensity, the two should be shown to occur not only in isolation with the same stimulus intensity, but also simultaneously at the same point of stimulation. The following series of test experiments were accordingly undertaken.

*VI. Mapping the Pain, Pressure, and Contact Points about the Hairs. Testing with Serial Stimulation.* For the first purpose the æsthesiometer, at an uniformly high intensity, was employed. The results went to show that the points of greatest sensitivity for the different qualities are usually distinct. When a series of graded intensities is applied to the different spots, contact-brightness and pain sensations usually emerge

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<sup>1</sup> Cf. *Jour. Amer. Med. Assoc.*, XLVII, No. 9, 1906, 647.

at the appropriate stage in every case, but on the pain or contact spots a dubious pressure or none is reported.

*VII. Mapping for Pressure, Contact, and Tickle with Stimulus Intensities of 25, 15 and 10 mg/mm.* A new hair, 0.23 mm. in diameter, was used. It gave in general its best pressure, contact, and tickle at the above intensities. Mapping was facilitated by the discovery that a quick short stimulation gave the best contact, while a more leisurely setting down and removal of the hair gave the more definite pressure. The tickle spots were found to coincide with the pressure rather than with the contact spots. Lifted folds of the skin and the region over the knuckles were also tested for pressure, which was easily obtained from the latter, but was apparently lacking in the case of the former.

*VIII. The Occurrence of Pressure and Contact in Conjunction in Certain Cases, in Disassociation in Others.* In the first case, prolonged stimulation with a blunted point, in the other the application of a series in the manner above described, was the procedure. In a large number of cases the observer reported the appearance of the two qualities together; sometimes the one, sometimes the other came out in advance, in accordance, apparently, with the direction of the attention. In a certain number of cases the contact reported later was probably a weak phase of a secondary pain. In the disassociation experiments, in which the area examined was first fatigued to pressure or rubbed with cocaine, the contact or brightness quality always suffered, while deep pressure was not only not at all weakened but apparently came out the more clearly in the absence of the superficial brightness.

So far, the results seemed sufficiently in harmony with our hypothesis. But the query now began to press as to the significance of what we have called our brightness or contact spots, occurring between the hair bulbs. Are these on precisely the same footing as the spots over the hair bulbs? Do they not possibly represent the free epidermal endings, *i. e.*, the pain spots of von Frey,—the contact or brightness quality being merely a fainter intensity of that sensation? The accidental discovery that superficial pain adapts out almost as readily as superficial contact gave further incentive toward the examination of this phase of the problem. The concluding experiments, which brought us ultimately to a more satisfactory conception of the quality of pressure, were devised more especially in the interests of this question.

*IX. Mapping for Pain and Testing for Contact-Brightness.* Precautions were taken to ensure the discovery of all the super-

ficial pain points on a given area of the arm; the skin was softened and a finely pointed needle was used. It seemed to us quite likely that so-called cutaneous pain is mediated by two sets of endings: the intense but quickly-fading variety by the epidermal nerve endings, the more severe and lasting (including ache and possibly secondary pain) by deeper (possibly vasomotor) endings. Our brightness sensation, if related to either, was most related to the former set. Hence in mapping we were careful to permit the point of the needle to penetrate only the superficial epidermal layers. After a due period of rest, the points so mapped were examined with the hair aesthesiometer (at about 23 mg/mm.), and were found to give in many cases the typical brightness (contact) sensation; in others, contact followed by a point of pain; or thirdly, where the epidermis was evidently injured or the region beneath had reddened, a pain which tended to outlast stimulation.

Later, in retesting for pain, the responsive point was often found to have shifted slightly, in a way corroborating Thunberg's hypothesis of an areal pain sensitivity corresponding to a tiny cluster of brush endings. The shifting would then represent the successive fatigue of endings within the same brush.<sup>1</sup> Mapping of the same area for pain with an overheated brass point, lightly applied, gave practically identical results as regards the position of the points and the occurrence of fatigue. That superficial heat pain is mediated by fatiguable nerve-endings is, of course, indicated by the rapid decrease of pain intensity on plunging the hand into a bowl of hot water. That this represents peripheral fatigue, not a mere loss of conductivity in nerve fibres in general, is indicated by the retention of other sensations, especially certain vivid (but unpainful) superficial sensations of pricking or tingling.

*X. Mapping for Contact-Brightness and Testing for Pain and Pressure.* An experiment complementary to IX. was then performed on a fresh area. The hair aesthesiometer at a length representing about 16 mg/mm was used; but in order to avoid a secondary pain response it was set down gently, and probably its effective intensity was somewhat lower. The points giving a clear brightness sensation were mapped, about 16 for an area of 3 by 10 millimeters, or approximately 50 to the square centimeter. This number is rather too large for the pressure spots of the area (on the volar side of the arm), and too small for the

<sup>1</sup> The possibility of fatigue in undifferentiated endings runs counter to current dogma, but there is (so far as the writer knows) no histological or physiological evidence of its impossibility in the case of the free epidermal endings; especially if, as seems probable, mechanical excitation itself is effective only through the production of chemical alteration in the nerve tissue.

pain spots, according to the calculations of von Frey. The area was next tested with a wooden point; some three or four of the marked points gave, not a single sharp sensation, but an obviously complex multiple of such sensations which was recognized as granular pressure; the others gave merely sharpness or a vague diffuse sensation. The hair aesthesiometer at 24 mg/mm intensity gave approximately the same results, the single points, however, becoming almost painful. The needle used in IX. was then applied gently to each point. Nine of the marked spots gave a lively pain immediately, sometimes, however, displaying an infinitesimal shifting of the point of greatest sensitivity. The rest gave granular pressure or nothing, while as many new pain points (about 16) again came to light in the gaps.

So far, then, it seemed clear that the bright component of granular pressure is fairly indistinguishable from the sensation arising from a weak stimulation of a superficial pain point; and, further, that the existence of contact points independent of pain and pressure spots is untenable. The question of the varying complexity of the sensations arising from hair-bulb stimulation, in comparison with the uniformly simple sensations arising from intermediate points, is one that requires further examination.

*XI. Mapping with Electricity for Pain and Pressure.* The interrupted current was used to explore an area on the lower arm. The indifferent electrode was bound to the arm with a damp sponge; the stimulating electrode was a fine point of copper wire. With gradual increase of the current, the observer reported the first appearance of sensation directly over the hair bulb as a faint "whirr" or cobwebby flutter or flicker, at times almost ticklish. Sometimes a brief stab, single or barely oscillatory, could be obtained from the intermediate regions with the same intensity of current. With approach of the primary and secondary coils the vague "whirr" over the hair bulbs became a "buzz," a complex tremolo of sharp, almost painful, points. Two such points of equal sensitivity were usually found in the vicinity of the same hair bulb. A similar response occurs in the intermediate regions only when the electrode is applied over a vein or artery, or when the current is strong enough to diffuse to neighboring hair bulbs. The sensation evoked in the interstitial spaces is usually sensed as a sharp, quick pain, immediately disappearing or fading into a weak, sharp tremolo or trill, quite different from the complex seething of hair-bulb stimulation. The pain itself, if not too sharp, may be perceived to possess an oscillatory rather than a steady character.

If the current is again increased, and fatigue of the area is avoided, the sharp "buzz" over the hair bulb seems to fuse into a tearing, rending pain, uneven, not perfectly continuous, and rapidly fading into a series of wrenching pricks which (while actually painless) excite a strong and almost reflex tendency to withdraw the arm. The pain thus evoked from the hair bulbs is strikingly different from the pain of the single intermediate points, which is fine and wirelike, while this is less abruptly penetrating but indescribably 'wrenching.' A similar distinction was made by one of the observers with regard to the pain produced by bristle stimulation of the hair-bulb and the intermediate regions. The former was characterized as sparklike, branching, explosive, aching, or dragging, the latter as wirelike, piercing. This difference is obviously less one of quality than of complexity, and the possibility is suggested that just as the granular sensation represents a synthesis of sharp points, so the hair-bulb pain represents the fusion of a number of single pain sensations.

In the course of this experiment, the discovery was made that a brief down-setting and removal of the electrode (with a moderate current) produced a fair imitation of the granular pressure of certain regions. This gave rise to the suggestion that the hitherto puzzling electric sensations from the hair-bulb represent merely a disintegration of the sharp component of the granular pressure, *minus* its duller, deeper substrate; and, further, that this sharp component represents the essential factor in granular pressure, the idea of compactness or solidity being derived from the manifolding and fusion of these components in the case of mechanical stimulation.

With the practice in analysis gained through these observations of electrically excited sensations in different complications, at different rates and at different points of fusion, the pressure sensations arising from mechanical stimulation on different areas were again passed in review, and a final estimate of the true pressure quality was attempted.

*XII. New Introspections on Granular Pressure.* From the cornea and conjunctiva no pressure, granular or diffuse, was obtained. Hairs of different sizes and loops of silk thread were used for the test. Sharp, punctiform, painful sensations uniformly resulted. The conjunctiva was less acutely sensitive, but the aching, areal sensation sometimes there evoked could never be identified as a dull pressure. The only tickle obtainable was painful.

On the mucous membrane of the mouth a good granular sensation could be obtained only by thrusting in the point of a needle. From the tongue, the hair æsthesiometer called out

only a sharp sensation, but by fusion with an aftermath of apparently reflexly excited sensations in the neighborhood this yielded a fair imitation of the granular sensation.

The observation that the "crunching" characteristic of granular pressure was best called out by stimulation over a bony substructure or on a calloused surface was now supplemented by the accidental discovery that on reddened or swollen areas the light, quick application of a needle point or hair gives, between the hair-bulbs (especially if the area is already fatigued to pain), a complex of unpainful, sharp sensations equivalent to a granular pressure *minus* the dull, deep component. If this sharp, thrill-like aspect of the pressure sensation were taken as the essential component of cutaneous pressure, the difficulty of classifying tickle as well as the electrically excited sensations with the cutaneous sense would lapse; the three would represent merely different spatial, temporal and intensive arrangements of the same elementary brightness sensation.

#### GENERAL CONCLUSIONS

1. *The Elementary Tactual Quality and the Histological and Physiological Conditions of Its Occurrence.* Three points out of the above observations are of special significance to our purpose.

(a) The complexity of the "brightness" component in granular pressure.

(b) The similarity of weak pain to any one of these bright components taken singly.

(c) The probability that these brightness components represent the essential, *i. e.*, the typical feature in granular pressure, and that the dull substrate which accompanies it under certain conditions is a secondary and probably a non-cutaneous factor.

Weighing these considerations, in common with the introspective evidence of Section B., we suggest that a single brightness or contact impression be considered the tactual unit. This qualitative unit, appearing in various groupings and intensities, may be sensed as granular pressure, contact, tickle, possibly even as pain. The bright, quick thrill of a light touch, and the stinging but unpainful sensations from twisting massage, may be considered as familiar representatives of this quality.

Physiological and histological conditions probably determine the variations in the form or pattern in which the tactual quality appears. The histological substrate of the sensations of light pressure is probably the Meissner corpuscle or the nerve endings of the hair follicle. The feature in common in the two

anatomical structures is the concentration of the terminations of one or more nerve fibres within a small space, accessible to stimulation from a limited skin area only. In the Meissner's corpuscle branches representing two, three or even more neurones (in the case of the larger corpuscles) break up into a complex network of varicose branchlets within a connective tissue capsule. In the case of the hair, only one nerve fibre as a rule reaches each follicle, at about half the distance down the root from the surface of the skin. This divides into two branches, from which numerous varicose fibrils proceed upward for a short distance parallel to the axis of the follicle, terminating apparently outside the glassy layer, that is, outside the solid structure of the hair root.<sup>1</sup>

Now, whatever may be the mechanical or molecular changes within the surrounding tissues which condition an excitation of these endings, it seems likely that the endings within a group are capable of individual response, that they may be excited singly, in irregular succession, in varying patterns and in different intensities, according as stimulation reaches them in the form of a single prick from the point of a needle, a light thrust from a blunter object, or the passage of an electric current. Possibly the chances of irregular stimulation are increased by some tendency toward periodic alteration in the adjoining tissues, *e. g.* through the vibratory movements of the hair or hair root. It is also possible that the endings are accessible to stimulation from more than one point on the overlying skin,—a possibility confirmed by our discovery of two to three points of almost equal sensitivity in the immediate vicinity of the hair follicle.

That the sensation resulting from the stimulation of such an ending singly should be identical with the quality resulting from the excitation of a free epidermal ending contains nothing *a priori* improbable. Histological evidence of the differentiation of the terminal fibres of either set of nerves is lacking; and, further, it has been shown that the hair follicles in general receive their nerve supply from the same fibres as terminate in the immediate skin area. While differentiation of quality is sometimes assumed to be centrally rather than peripherally conditioned, it would seem probable that the original motive to such differentiation sprang from some peripheral stimulus difference. Now the adequate stimulus of both pressure and pain is mechanical, differing only in area or penetrativeness and in intensity. While this difference is of the highest biological significance (since highly intensive stimuli are almost uniformly injurious to the tissues), it seems possible that it is amply represented in the interests of biological functioning and of protective reflexes by the functional and anatomical independence of the two sets of nerves, for pressure and pain proper. In the one case (that of the epidermal endings) we have great accessibility to such external stimuli as would tend to pierce or

<sup>1</sup> A. A. Böhm, M. von Davidoff, and G. C. Huber: *Textbook of Histology*, 1904, 393-4.

penetrate the skin; in the latter (hair wreath or Meissner corpuscle) we find an arrangement whereby the endings are both protected from excessive stimulation and fatigue, and fitted for the perception of the faintest impressions, through the multiplication of the number of endings distributed within a minute space or by a special device (the hair) for magnifying the mechanical effect.<sup>1</sup> This anatomical and functional separation of the two sets of nerves insures, of course, distinct reflex arc connections for the two grades of stimuli.

From the point of view of consciousness, the distinction between blunt and sharp (*i. e.* the areal difference in stimuli) is provided for by the complexity or simplicity of the resulting sensory process in the two cases, the sharp response (from pain or pressure organs) being possible only with sharp and penetrating or pointed objects, the granular or pressure sensation arising ordinarily from objects presenting some surface. The distinction between extremes of intensity may possibly be represented by a qualitative distinction dependent not on differentiated endings but on independent central stations for collaterally and directly conducted impulses; the collateral connection would then lie open only to high stimulus intensities. In any case, the motive for qualitative differentiation of pain and pressure within their lower range of stimulus intensities is not conspicuous, and this is the point with which we are here concerned. Upon the actual fact of the likeness of the simple tactal quality and the distinct but painless response of a pain spot to moderate stimulation, we believe the testimony of introspection to be sufficient.<sup>2</sup> The readiness with which the latter sensations pass over into positive pain has doubtless contributed to screen them from comment.

To return to the pressure-unit concept, and to recapitulate: the granular pressure of Goldscheider was, as our introspections showed, a complex sense-experience. The desirability of retaining within the category of pressure such semi-disintegrations as tickle and electrically excited sensations forced us toward recognition of this complexity and revision of our pressure-concept. In the accomplishment of the latter task we have discarded the dull substrate of the granular pressure of our earlier observations as an inessential concomitant of cutaneous pressure, having its origin probably in the subcutaneous tissues.<sup>3</sup> Abstracting from this deeper component, we find the isolated skin pressure still complex or "granular," made up apparently of a number of simple tactal impressions whose description is impossible except by such adjectives as sharp, bright, punctiform. The application of the term 'pressure' to this sensation seems unfortunate, since the prominent component in the 'pressure' of ordinary speech is undoubtedly not

<sup>1</sup> Cf. W. Wundt: *Physiologische Psychologie*, 1902, I, 400.

<sup>2</sup> The existence of a range of fairly unpainful pain sensations, corresponding to the response of the pain endings to a lower range of stimulus intensities than is usually thought possible, is of interest more especially in relation to the origin and explanation of organic sensation, in connection with which it will receive fuller discussion in a later article.

<sup>3</sup> The question of the uniqueness of its quality is reserved for later discussion.

the granular quality but the deeper element which we have just thrown out of the discussion. The expression 'light pressure' or 'touch' would seem to be the least ambiguous.

Careful examination of Goldschieder's monographs on cutaneous sensation reveals many unexpected congruities between his observations and our own. In the interests of the doctrine of specific energies, we find many qualitative phases of cutaneous sensation carefully examined and recorded. Among these are certain trenchant descriptions of pressure-spot stimulation, phrased in terms which are a tacit recognition of the complexity of the so-called granular sensation. The characteristic feeling is "kein eigentlich punctiformes" but "als ob man auf ein feines Körnchen Staub drückt";<sup>1</sup> "wenn man auch nicht sagen kann dass er flachenaft irradiiert wie bei den Temperaturpuncten, so ist er doch breiter als zum Beispiel die stechende Empfindung, welche in der That als punctiform zu bezeichnen ist. Man könnte das Druckpunktgefühl vielleicht als ein dem punctiformen nahekommenches aber volleres Gefühl bezeichnen."<sup>2</sup> The discovery which Goldscheider here believes himself to have made is that the pressure sensation, even in the last analysis, is not punctiform but retains its characteristic pressure quality, *i. e.*, its spatiality, solidity. This solidity, of course, we should maintain to be, not a characteristic of the ultimate unit, but a correlate of the complexity of the granular pressure itself.—

This point comes out more clearly in the contrast drawn between pressure-point stimulation and that of intermediate regions. On the latter the sensation is either "ein mattes unqualifiziertes," or on certain points, with sharper stimulus, "mehr stichartig, das heisst, ohne Schmerz, aber auch ohne die qualifizierte Tast- und Druckempfindung, dünn, inhaltlos." This "stechende Gefühl" of the intermediate points, which with increased intensity easily passes over into a painful prick, corresponds evidently to our bright sharp sensation, and the points on the skin to our original contact points. These points were at first distinguished by Goldscheider from the pain points proper, but the distinction was later recognized as one of limen only, and the two were grouped together and referred to the *Gefühlsnerven*. This setting-off of *Gefühlsnerven* from *Drucknerven* corresponds, according to Goldscheider, to a functional rather than a qualitative differentiation. It represents a separation of function in the perception of the objective as over against the subjective aspect of experience. The *Gefühlsnerven*, branching everywhere in the skin, render

<sup>1</sup> *Gesammelte Abhandlungen*, 1, 1898, 187.

<sup>2</sup> *Ibid.*, 191.

it sensitive to mechanical stimuli in general and to intensive stimuli in particular. The specific pressure-nerves, on the other hand, are especially adapted to the perception of low intensities and intensive differences, and of small differences in locality.

The pain into which this "punktformige" quality, produced by the stimulation of the *Gefühlsnerven*, goes over with increase of intensity is described as "ein schmerhaft stechendes, welches durchdringend, lancierend, und meist in Moment des Entstehens am stärkesten ist, um trotz Fortdauer des Reizes schnell zu erlöschern." The painful excitation of a pressure point, on the other hand, makes a more powerful impression on the sensorium, lasts as long as the stimulus, with a tendency to grow stronger rather than to weaken.<sup>1</sup> The passage in this case of the granular pressure into pain is described as a transition into a "ziehendes, druckendes, quetschendes Schmerzgefühl," as over against the "stechartiges lancierendes" of the intermediate points; a distinction similar to that made by one of our observers.

According to Goldscheider, then, there are two sets of points on the skin, of which the one may yield a *Beühring* (or *Kitzel*)-*Druck-Schmerz* continuum, the other a *Berühring-Stich-Schmerz* series, the former mediated by *Drucknerven*, the other by *Gefühlsnerven*. The precise relationship of the *Druck* and *Stich* qualities (both of which are said to shade into pain at the upper end of the continuum) is left uncertain. Pain, when not too intense, is said to have "gewisse verwandtschaftliche Beziehungen zu Berührungs- und Druckqualitäten," but the anomaly of its appearance at the summit of two disparate continua is left unexplained (unless the hypothesis of gray-matter conduction in either case be taken as an explanation). Our interpretation, while doing justice to the shades of similarity and difference noted by Goldscheider, would simplify explanation by reducing the distinction between the *stichartiges* and *körniges Gefühl* to one of complexity and not of quality, and by assigning certain aspects of so-called pressure to deeper, non-cutaneous endings.

A word may be added in conclusion, in support of our proposed simplification of the pressure concept. It may be objected that to push analysis beyond the normal functional unit, *i. e.*, granular pressure, is a work of supererogation; a sense contents is practically unitary as long as it evades analysis, and this the granular pressure normally does. In reply we can only urge that a unit which may go to pieces in the hands of the experimenter is, under any conditions, an unsatisfactory basis of op-

<sup>1</sup> *Op. cit.*, 198.

erations. To be useful in investigation, a unit must be not only unanalyzed but unanalyzable, as our difficulty in identifying tickle and electrically excited sensations with the pressure quality has shown. Further illustrations of this point may be drawn from the sphere of semi-subjective sensory complexes, cutaneous and organic, where the danger of mistaking what we may call (in analogy with *Klangfarbe* in tones) the form-color or quality of a sense experience for ultimate qualitative contents, *i. e.*, for a new quality, is constantly present. In accordance with our original purpose, we insert under the next heading a description and tentative analysis of some of the simpler of these complexes as encountered in the study of pressure.

2. *Form-Color: The Apparent Metamorphosis of Sense Qualities through Elaboration.* For the study of apparent alterations of quality through reduplication and complication, stimulation of the skin with the interrupted current is invaluable, affording, as it does, from moment to moment transition phases in the formation and disintegration of fusions and complexes. The conception of granular pressure as a fusion of points on the verge of disintegration because of temporal or intensive oscillations, and the possibility that just as granular pressure represents a half-fusion of sharpness-units so dull areal pressure represents a smooth fusion of low intensities of the same units, were suggested by the use of the interrupted current.

a. *The Qualitative Validity of the Term 'Dull.'* Even if the dull component of our original granular pressure arises from a distinct set of deeper endings, its qualitative uniqueness is by no means assured; it may represent merely a blurring together of sensation-units similar to those of our superficial tactal quality. Attention was drawn to this speculation by the following observations. First, the after-image of a "fizzly" or ticklish pressure, *e. g.*, the sensation resulting from a light thrust on a swollen and reddened area or the palm of the hand, often approximates the dull, "cottony" unanalyzability of our deep pressure. Secondly, with continued faradic stimulation of the skin, a certain zone of sensation tends to lose its prickly intermittent character and to approach the dull areal pressure quality. A similar experience follows the holding of a finger against the vibrator of an inductorium or the end of a tuning fork; at a certain point of fatigue and dulling of the original bright intermittent sensations, the disparate vibrations become more and more indistinguishable, until finally the complex falls just below the level of analysis and a dull smooth areal impression succeeds. A similar gradation into dull pressure occurs in the dying away of the tingling of a limb which has

been "asleep" into either a massive dull sensation or a mass of soft blurred barely analyzable fluttering sensations. That is, the appearance of a dull massive contents marks apparently not the transition to another quality but a stage in the amalgamation of otherwise punctiform sensations. Hence the dull pressure of ordinary speech, even if mediated by deeper endings, conceivably represents not a quality peculiar to them, but a fusion of sensations like in kind to our elementary tactal quality, but of moderate intensity (the endings being secured against violent stimulation) and continuous, not irregular. That is, dullness may represent a certain "form-color" rather than a primitive quality: the terms massive, solid, may refer less to intrinsic qualitative attributes than to associated imagery, such as the hazy visualization of the tridimensional objects by which the displacement of deep pressure is ordinarily effected, or to a vague consciousness of the spatiality of the region of the body affected.

*b. Sharpness.* A similar query as to the status of the adjective 'sharp' rose in connection with the characterization both of tickle and of electrically excited sensation. The possible interpretations fall into two main categories: either sharpness represents an original quality, hardly susceptible under any conditions to clouding and blurring; or sharpness is simply a function of the isolated appearance of a sensation, hence capable of attaching itself to any quality indifferently. The latter possibility is itself susceptible of various explanations, *e. g.*, the following:

(1) Sharpness or pointedness may represent the opposite or absence of extendedness. Extension or surface may be an associative factor, visual or kinæsthetic, set up only when the stimulation affects two or more points. Hence pointed or sharp would be the equivalent either of absence of visualized extent, or of visualization of a single point.<sup>1</sup>

(2) Sharpness may denote the absence of the fringe or halo of weaker sensations usually present as a result of the diffusion of stimulation to adjacent endings. In other words, it may represent not an attribute of sensation but a relation to other contents, *i. e.*, definiteness of outline, or sharpness of differentiation from the context.<sup>2</sup>

(3) Sharpness, in its cutaneous application, may signify merely abruptness of rise and fall of sensation, clean temporal definition; correlated in tickle with the oscillating intermittent

<sup>1</sup> We have no intention here of raising the question of the spatial attribute as intrinsic to the tactal sensation. The point at issue is merely the presence or absence of an appreciable *surface*.

<sup>2</sup> Sharpness in this sense is practically equivalent to 'distinctness' in the usage of Wundt.

character of the sensations, in contact or light touch with abruptness of appearance and disappearance, in contrast with the gradual swelling out and dying away of a dull, heavy pressure.

(4) Lastly, sharpness or brightness may connote merely a vividness, penetrativeness, correlated with the concentration of attention on a single process as against its customary dispersion over a total contents representing several processes. For example, the sharpness or vividness of a pain sensation may be largely a function of its monopoly of the focus of attention.

As the result of many observations the decision was finally reached that the contents described as sharp is really the *typical tactful quality*, capable, to be sure, of definite dulling or brightening, under the influence of variations either in intensity or in any one of the four conditions above listed.

*c. Principal Types of Form-Color in Tactual and Kinæsthetic Sensation.* Parallel with the above study, the working over of a number of introspections on sensory complexes akin to the organic (accumulated in connection with the analysis of granular pressure and tickle) was attempted. The plan adopted was to select certain of the specific sense-experiences arising from the excitation of the skin and immediately underlying tissues, to examine the transitional phases, and to determine how many of the differences accepted at first sight as ultimate resolve themselves on analysis into differences in the consolidation or co-ordination of the component sensations. The gooseflesh shudder, the tingling following a sharp rap on the hand, the "waking up" of a limb which has been asleep, and the ordinary muscle, joint, and strain sensations were carefully observed in their waxing and waning,<sup>1</sup> with the results recorded below.

The sensation of stretching or tautness of the skin, common to certain stages of the gooseflesh shudder, electrical excitation, and the after-phases of the sensations associated with tickling and a smart blow on the skin, we were at first inclined to regard as a specific quality, having its origin in the sensory endings in the plain muscle fibres of the skin and excited by the contraction of the latter. Since, however, this unique sense-experience was observed always to accompany the dying away of an extended field of sharp intermittent sensations, the suggestion forced itself on us that this also was a case of peculiar

<sup>1</sup>This procedure approaches as nearly to the "synthetic experiment" as our lack of knowledge of the precise excitatory conditions in the various phenomena would admit. It is, of course, open to objection in that apparent gradations in a homogeneous complex may really mean the gradual swamping of one quality through the emergence of another. The error thus introduced we believe, however, to be inconsiderable with practice in analysis.

"form-color," the mode of appearance in consciousness of an extensive incorporation at a certain stage of consolidation or blurring. That is, the tension in the gooseflesh complex represents a closely woven web of superficial sensation, from which deeper components are lacking. This unique tactal formation, excited ordinarily only by stretching of the skin, serves as a functional unit or symbol for a single objective fact, *i. e.*, tension, and has thus won for itself a solidarity or unitariness which enables it to pass itself off as a specific quality.

A second set of sensations which seemed likely to defy analysis was that of strain. The strain complex, as it occurs in association with vigorous contraction of the skeletal muscles, is distinctly localizable in the tendinous regions near the attachments of the muscles. In comparison with the sense contents of either articular or muscular sensation, it is in its higher intensities unique, and might be characteristically described as suggestive of an iron tension or rigidity. This characteristic contents was, however, observed to occur in other contexts than that of muscular tension or exertion, and in various regions. In the reflex excitation of the salivary glands by sour liquids or odors, in general physical fatigue, in neuralgic headache, in a certain intolerable phase of the tingling of a foot or arm which has been asleep, and after prolonged application of icy objects to the skin, very fair imitations of the tendinous strain quality occur. It seems improbable that in all these cases specific end-organs of strain are affected; and indeed the observations on the transitional phases and gradations in electrical sensations, tingling, and glandular excitation, all go to show that strain, like stretching, represents the welding of a certain group of sensations of the bright tactal quality.<sup>1</sup> As sense contents it differs from stretching mainly in its greater bulk and intensity, and possibly in a greater compactness and closeness of union between its individual members. Here again the unitary functioning of the complex (in tendinous strain) has furthered the specific quality deception.

Thirdly, the sensory contents of the numbness following fatigue or stoppage of the circulation was examined under different conditions, and was found on close scrutiny often to resolve itself into a multitude of dulled unsteady shadowy sensations, giving a total impression of massivity, tridimensionality, but possessing neither the smoothness nor the stability of the ordinary dull pressure experience.

Lastly, the "circulatory" complex or tingling in "pins and needles," the uniqueness of which as conscious contents is

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<sup>1</sup>Whether mediated by superficial or deeper endings in any given case is hardly determinable.

unquestionable, was found to present a close parallel both to intermittent electrically excited sensations and to the goose-flesh shudder which, under close observation, is plainly pricking at a certain stage. If we accept the electrically excited sensations as a peculiar disintegration of the granular pressure, and recognize their close similarity to the so-called circulatory sensations, the necessity for forming a special category for the latter lapses, and their uniqueness may be construed as residing not in the individual, but in the aggregate or collective aspect of the complex, the 'form-color.'

In the light of the above introspective evidence it would seem possible to classify these apparent cases of specific quality as complexes or extensive incorporations of varying degrees of consolidation. Three distinct types, representing as many degrees of fusion, may be deciphered. These may be schematically indicated as follows:

(1). The most stable: below the limen for analysis. Two sub-types may be distinguished on the basis of intensity and disintegration: *a*. a smooth fusion or blurring-over of sensations of weak intensity, with incentive to analysis lacking: illustrated by dull pressure or muscular fatigue; *b*. a firm fusion, of considerable intensity, with no tendency to disintegration, illustrated by the sensation of strain.

(2). Of less stability: much blurring and weak intensity, but a slight irregularity or intermittence in single members of the group, which brings the complex just up to the limen for analysis: feeling-tone uncanny, "nervous." Illustrations: numbness, some shades of tickle, the after-image of pressure, the response of a fatigued pressure spot.

(3). Noticeable instability: kaleidoscopic changes; obviously a plurality of sensations, whose intermittence and degree of intensity are both favorable to analysis. Pricking, tingling, and electrically excited sensations are examples.

To those inclined to posit definite boundary lines between pain, pressure, joint, muscle and strain qualities, this attempt to reduce the whole *Gefühlssinn* to a common denominator will seem extreme. Wundt is perhaps at present the sole representative of the school who found in 'touch' a category sufficiently comprehensive for all mechanically excited sensations, external or internal. The tendency of the present is in favor of multiplication of qualities, and the effort to push analysis behind the accepted psychological atoms or indivisibles in the interest of a further simplification of qualities will probably be deemed as fanciful as Leibniz' or Spencer's postulation of unnoticeable part-processes. The dissection here carried out, however, is not purely hypothetical, but was effected in almost every case directly by introspection. Further, while it is un-

deniable that the unlikeness of the experiences cited is functionally more significant than their ultimate homogeneity, work in the new sphere of organic complexes would have been almost impossible without the aid of the concepts of combination or complication thus acquired. From the point of view of method, therefore, such distinction is amply justified.

These supplementary studies have further shed light upon the conditions and significance of certain judgments involved in the description both of tickle and of organic sensation. Before passing to the discussion of tickle, a brief section will be devoted to this subject.

3. *The Sensory Basis of Certain Judgments: Localization, Intensity, Area, etc.* The point here raised is not that of the accuracy of external reference and projection in general, but merely of the reliability of certain judgments as a basis for inference regarding the precise origin and explanation of various phenomena,—tickle, tingling and the like. The question may be formulated as follows. To what extent do apparent localization, intensity, and volume depend directly and unequivocally on sensation attributes and differences? How far are they mediate rather than immediate perceptions, dependent on certain intervening assimilatory ideas and associations,—and thus, for our purposes, open to suspicion? Prolonged introspective study seems to show that visual imagery and stimulus-reference, correlated with variation rather in sensation pattern than in the immediate sensation attributes, form in many cases the important factor.

(a) *Intensity.* In the intensity judgments, heavier and lighter, stronger and weaker, variation in the total sense contents enters into the judgment as follows. Even with a punctiform stimulus, variation occurs in the amount of diffusion of stimulation superficially and in the third dimension. Hence the observer frequently reports that the extent to which weaker outlying sensations, or a deeper component, dull pressure or ache, are present forms the basis of his judgment; while visualization of the amount of surface indentation often forms an intermediate link. Interpretation of the stimulus is, therefore, commonly confused with sensation intensity pure and simple. Only thus could the common error have arisen that tickle is characteristically weak and faint as compared with contact and pressure sensations; its customary stimulus is weak, but its own intensity is really in keeping with the energy of the response which it excites.

(b) *Spatiality; Extendedness and Solidity.* The distinction drawn by our observers between pressure and touch as tridimensional and bidimensional resolved itself, in the majority of

cases, into a matter of visual association. Bright sensations of a certain intensity and massing are almost indissolubly associated with superficial stimulation, *i. e.*, with the surface of the skin. Whatever is closely associated with visualization of the skin must get thereby (if it does not have it originally) area, bidimensionality. Further, a certain pattern of dull massed sensations is associated in experience with the partial displacement of some fleshy portion of the body, and is never actually projected to the surface. Hence the tridimensionality or solidity of muscle or deep pressure sensations is apparently borrowed from the suggestion of volume in the associated imagery. The significance of the term 'point,' on the other hand, seems to connote an almost total absence of body, of spatiality, and is associated with a lack of projection or objectivity.

(c) *Localization in the Third Dimension.* Tickle is sometimes localized "just under the skin," dull pressure always. Secondary pain seems to spring up from below, pins and needles seem to dance to and fro in the third dimension, penetrating toward the surface and retreating. Evidence in favor of assigning these sensations invariably to deeper lying endings is, however, lacking. The "depth" perception is dependent on certain habitual principles of objective reference, which, while misleading for our purposes, in the majority of cases work satisfactorily to the organism. The important question ordinarily is not in what layer are the nerve endings affected, but what is the situation of the exciting cause: and the customary spatial interpretation represents with sufficient accuracy the answer to this question. Itch, secondary pain, pins and needles and the like are conditioned immediately by processes within the skin. The immediate incentive to inward localization in these cases is, doubtless, furnished by temporal inertias and irregularities which experience has correlated almost invariably with internal rather than external stimulation.

(d) *Movement.* The apparent advance and retreat in the third dimension in "pins and needles" suggest the basis of certain illusory judgments of movement. It seems improbable that the apparent travelling or creeping on the surface for minute distances of the faint tickle-sensations excited by punctiform excitation actually represent either the successive stimulation of different nerve-endings or central irradiation. It is not unlikely that, in analogy with the judgment of apparent movement in pins and needles, slight oscillations in intensity or even irregularity in the successive response of the endings belonging to a single pressure point are interpreted as linear movement on or just below the surface.

(e) *Projection in General.* The conditions which determine the completeness of development of projection or objective ref-

erence in any case—*e. g.*, to the body wall, to the body surface, or beyond the surface in visualization of the stimulus—have been indicated under the preceding heads. The conditions which prohibit the passage of a sensory complex beyond the bounds of the subjective, preserving it as an affective rather than a sensory phenomenon, will be discussed at more length in connection with tickle.

## SECTION B. TICKLING

### HISTORICAL: THE PROBLEM OF TICKLE

The peculiar affective reaction excited by a light touch has long been a matter of remark among psychologists and biologists alike. The fact that a feeble stimulus evokes such an exaggerated commotion in consciousness, whereas a heavier one remains indifferent, presents a paradox to psychophysics which has never been satisfactorily explained. The observation that this affective disturbance, which is sometimes pleasant, sometimes uncannily unpleasant, is in some individuals entirely lacking only adds to the difficulties of explanation.

The older psychologists, of semi-physiological bent, threw the burden of explanation upon the obscure concept of "central irradiation," and were content when they had classified tickling with the *Gemeinempfindungen*, the unprojected, ill-analyzed masses of bodily sensation, which function as subjective and affective rather than objective and perceptual. Later, a biological interpretation was attempted, and various speculations were advanced as to the significance in the past history of the race of the reflex vigor and affective response now associated with tickling. Lastly, experimentalists have attacked the problem, and sought to discover in the histology and physiology of the skin, and in the immediate sensory contents of tickle, the peculiar conditions by which it is set apart from cutaneous sensation in general. It is with this latter phase of the investigation that we are here immediately concerned, believing that it alone can afford a satisfactory basis for the explanation of the peculiarities of the tickle consciousness as a whole.

#### *1. Tickle as centrally conditioned, non-projected sensation (Gemeinempfindung or 'feeling').*

This type of explanation originated with Weber, but has since undergone elaboration at the hands of Wundt, von Frey and others. The uniqueness of tickling, as of the related experience of gooseflesh, resides, it is held, in the eccentricity of its temporal course (inertia of appearance and disappearance), and in its tendency to diffusion or irradiation. In consequence of these peculiarities, exact correlation between stimulus and

sensation is impossible, and tickle remains among the sensory experiences which fall short of projection beyond the physical self, *i. e.*, among the *Gemeinempfindungen*. With organic sensation proper this failure of external reference may be ascribed to the internal or subjective nature of the stimuli. Tickling, in spite of the external character of its primary stimulus, presents a parallel case; for its actual constituents are secondarily excited sensations (*Mitempfindungen*, in the terminology of Quincke), the temporal and spatial course of which corresponds only remotely with that of the original stimulus.

The mechanism by which these secondary sensations are excited is explained by E. H. Weber,<sup>1</sup> and after him by O. Funke,<sup>2</sup> H. Quincke,<sup>3</sup> W. Wundt,<sup>4</sup> and M. Dessoir,<sup>5</sup> as purely central, an, irradiation confined to the sensory centres or ganglia, and referred to the surface only through a special form of excentric projection. Another set of writers, B. Bourdon,<sup>6</sup> M. von Frey,<sup>7</sup> O. Külpe,<sup>8</sup> A. Allin,<sup>9</sup> C. S. Sherrington,<sup>10</sup> and in some passages Wundt favor irradiation from sensory to motor centres. According to the latter theory, diffusion or irradiation, while centrally conditioned, takes effect peripherally, through the agency either of vasomotor changes or of the contraction of the unstriated muscle fibres of the skin. Among the supporters of the vasomotor theory, von Frey and Bourdon admit the possibility that tickle constitutes a specific sense, distinct from pressure, with endings of its own in the skin or vessels, Bourdon maintaining that pleasure itself is a diffuse sensation of tickle. Külpe, on the contrary, holds that tickle contains no new element, but represents a combination of the qualities of pressure and temperature characterized by rapid alternations of contents and intensity, and closely related to tingling and itch. Wundt, in the Human and Animal Psychology, suggests that sensations from the reflexly excited unstriated muscle layer in the skin combine with the feeling of tickling, lending color to the total impression. Sherrington goes further, regarding tickle as "a peculiar psychic elaboration of tactful and muscle impressions,

<sup>1</sup> E. H. Weber: *Der Tastsinn und das Gemeingefühl*, 1851, 565-6, 578-9.

<sup>2</sup> Hermann's *Handbuch der Physiologie*, 1879, III, 313.

<sup>3</sup> Über *Mitempfindungen*, *Zeitschrift für klin. Medicin*, XVII, No. 5, 1889, 443.

<sup>4</sup> *Grundzüge der physiologischen Psychologie*, 5te Aufl., II, 42.

<sup>5</sup> Über den Hautsinn, *Du Bois-Reymond's Archiv*, 1892, 237.

<sup>6</sup> La sensation de plaisir, *Revue philosophique*, 1893, XXXVI, 225.

<sup>7</sup> Untersuchungen über die Sinnesfunktionen der menschlichen Haut, 1896, 217.

<sup>8</sup> *Outlines of Psychology*, 89.

<sup>9</sup> On Laughter, *Psych. Review*, X, 1903, 307-8.

<sup>10</sup> E. A. Schäfer's *Textbook of Physiology*, 1900, II, 976.

the latter arising from the reflex activity of the unstriated muscles of the skin, pilo-motor, sudorific and vasomotor."

*II. Tickle as giving rise to affective disturbances and reflexes.* In this connection three different explanatory factors have been advanced, the summation of intensities, psychical attitude, and the inheritance of adaptive reflexes.

*Summation of intensities.* According to E. Kroner,<sup>1</sup> summation of intensities in sensory centres and nervous excitability furnish the explanation of the disproportion between the intensity of the stimulus and the resulting disturbance in consciousness. Allin<sup>2</sup> favors motor rather than sensory summation, quoting Stirling's observation that reflex contractions occur only from repeated shocks in nerve centres. Tickle, he suggests, may represent a sudden convulsive hyperæmia (presumably cerebral) entailing an explosive motor discharge, as contrasted with the diffused hyperæmia of a steady pressure. A possible cue to the difference in the reflex effect of a light and heavy touch is also offered in Lauder Brunton's suggestion that the latter may stimulate two sets of nerves which counteract or inhibit each other.

*Psychical attitude.* A second possibility has been advanced by C. Darwin<sup>3</sup> and approved by K. Groos,<sup>4</sup> E. Kroner, J. Sully,<sup>5</sup> and others, to the effect that the reflex disturbance of tickling (as evoked in movements of laughter, of withdrawal, and of either protective or purposeless character) is conditioned not by the peculiar characteristics of the initiatory sensation, but by the psychical attitude or disposition upon which such sensations are superimposed. Darwin finds surprise or novelty the all-important factor, and thus reduces the tickle reflex to an expression of emotion. He supports this conclusion by the facts that the parts of the body most sensitive to tickle are those not commonly touched or touched in tickle in an unusual fashion, that the part to be tickled must not be known, and that one cannot tickle oneself. According to Sully, the mental agency conducting to tickle is in the nature of shock or relief: a sense of the unknown or unpredictable in the situation, followed by the recognition of the merely playful character of the attack. Laughter itself is probably a physiological device for

<sup>1</sup> Das körperliche Gefühl, 1887, 164, 200 ff. E. C. Sanford also classes tickle as a summation phenomenon, citing in evidence the fact that a light touch with the prong of a tuning fork is often ineffective when a vibrating prong is immediately productive of tickle. Experimental Psychology, 1898, 18-19.

<sup>2</sup> On Laughter, *Psych. Rev.*, 1903, X, 306 ff.

<sup>3</sup> The Expression of the Emotions, 1872, 201-2.

<sup>4</sup> The Play of Man, 1901, 165.

<sup>5</sup> Essay on Laughter, 1902, 59-61.

the relief of cerebral strain. The stimulation of deeper lying endings is not essential.

A third interpretation regards the reflex response as *the survival from some ancestral instinct*, the significance of which is not perfectly apparent. Various possibilities have been suggested. According to the first, tickle is a relic of a primitive contact-sense, which existed before the development of the senses of 'anticipatory touch,' and necessarily possessed a high dynamogenic value and lively reflexes; when danger was announced only by contact, with great suddenness, strong reactions of escape or resistance were necessary. G. S. Hall and A. Allin<sup>1</sup> and Bronson<sup>2</sup> support this view, the former citing in evidence the fact that the parts of the body most sensitive to tickle are those most vulnerable or most open to attack, *e. g.*, the soles of the feet, palms, and throat, in contrast with the shoulder-blades, calves and thighs. The suggestion is also made by Hall and Allin, and approved by Sully, Sherrington, and others, that the necessity for protection against the incessant attacks of insect parasites has played an important rôle in the maintenance of this sense. A similar explanation is put forward by L. Robinson,<sup>3</sup> according to whom tickle is distasteful or agreeable according as it represents a warning against insect foes or possesses some obscure associations with caressing movements dating back to an early stage of existence.

*III. Tickle as a Sense Quality. (a) Relation to Touch.*—In the general literature, tickle is identified more or less closely with contact, touch, or pressure, with itch or with the goose-flesh shudder. Bronson and Dessoir<sup>4</sup> separate touch or contact from pressure, assigning tickle to the former sense; Goldscheider,<sup>5</sup> Kiesow,<sup>6</sup> and L. Herrick<sup>7</sup> classify tickle with pressure, limiting it, however, to cases of a peculiar functioning of the specific pressure organs; Külpe<sup>8</sup> and Wundt, while iden-

<sup>1</sup> The Psychology of Tickling, Laughing and the Comic: *Am. Jour. of Psych.*, IX, 1897, 14.

<sup>2</sup> *The Medical Record*, xxviii, 425.

<sup>3</sup> Cf. Tickling: H. Tuke's *Dictionary of Psychological Medicine*.

<sup>4</sup> *Op. cit.*

<sup>5</sup> *Gesammelte Abhandlungen*, i, 1898, 45.

<sup>6</sup> *Zeitschrift f. Psych. und Phys. d. Sinnesorgane*, xxxv, 1904, 240-1.

<sup>7</sup> Corollaries of Neurological Discoveries, *Jour. Comp. Neurology*, 1897, 160.

<sup>8</sup> Outlines of Psychology, 89. According to Külpe, tickling often accompanies the weak or intermittent stimulation of a pressure organ. Since a gentle pressure or blowing on the skin is found to be often followed by increase in arterial pressure which intensive or even painful stimulation is unable to effect, it seems probable that "certain processes in the cutaneous vessels serve as the substrate of the impressions of weak pressure and more or less vivid heat which occur in quick alternation in both tickling and itching."

tifying the essential constituent as tactual, recognize the presence of an added element, reflexly aroused by vasomotor or other changes, in the form either of warmth or of muscle sensations.

The distinction drawn by Dessoir between tickle and pressure is really, however, perceptual rather than qualitative and is based upon the absence of externalization in the former sensation; he does not posit a distinct set of endings for his contact-tickle sense. Kiesow identifies tickle unequivocally as a pressure or *Tastempfindung* arising from the direct excitation of a pressure organ, intimating, however, that the stimulation must be accomplished through the medium of the hair, *i. e.*, by vibratory or intermittent excitation. Herrick, though failing to work out any definite conception of the relation between tickle and pressure or touch, explains the diffuse irradiating character of tickle by reference to the anastomosis between tactile corpuscles noted by Dogiel<sup>1</sup>. Goldscheider,<sup>2</sup> while ultimately falling back on a variation of the *Gemeinempfindungen* concept, attempts to explain the peculiarities of tickle by reference to the mechanism and characteristics of the sense department to which it belongs (pressure in his system). While his observations are merely incidental to the investigation of pressure, and are limited to tickle sensations initiated by punctiform stimuli, they bring to light many important facts. Of these the following, since disputed by Alrutz, are noteworthy. First, tickle may appear simultaneously with the sensation of touch which frequently attends it, *i. e.*, a delay between stimulation and the appearance of the sensation is not characteristic. Secondly, there are no specific tickle points; exploration of the skin with a bit of cork discloses tickle only over the *Druck* or *Schmerz* points. Other observations mark the correlation of tickle with weak mechanical or electrical stimulation of the skin: its liability to fatigue; its high affective value and qualitative indefiniteness; its long after-image and the tendency of this after-image to fade indistinguishably into touch; the peculiar distribution of tickle sensitivity, and the inverse relation of the tickle range of any area to its pain and pressure sensitivity. From these observations, Goldscheider draws the conclusions that tickle represents not a secondary sensation, but the direct result of weak mechanical stimulation of the pressure endings, a belief in which Kiesow alone seems to support him.

<sup>1</sup> Cf. Wundt's speculation on the function of the Krause endbulb, *op. cit.*, 13, for a similar suggestion.

<sup>2</sup> Cf. *Die specifische Energie der Gefühlsnerven der Haut*, 1884, 45, 46, 81, 82; and *Neue Thatsachen über die Hautsinnesnerven*, 1885, 202-4.

The precise manner in which Goldscheider conceives the relation of tickle and pressure differs slightly in the two monographs cited. In the first he maintains that the qualitative continuum of touch or pressure is threefold, comprising tickle, pressure and pain, each representing a special shading, as it were, of the elemental quality. For the production of tickle neither successive stimulation of different end-organs nor repeated stimulation of the same end-organ is necessary; tickle is the "eigentliche specifische Empfindung der Tastnerven" and arises normally from any single weak stimulation of the end-organ. A single stimulation probably gives rise, however, to a whole series of successive disturbances or excitations within the sense-organ. Weak mechanical stimulation is probably the condition most favorable to the uniformity and continuance of this series of excitations, which is perceived as tickle and is pleasant. When the mechanical shock is sufficient to affect the surrounding tissues, the commotion there produced reacts upon the end-organ and either damps off its vibrations or disturbs their regularity. This new state of affairs is transmitted to consciousness in terms of indifferent touch.

On the basis of this hypothesis the correlation of tickle with weak stimulus intensities and its long after-image are readily explained. Two points, however, remain obscure. First, does Goldscheider regard the oscillation ascribed to tickle as a central and conscious matter, or as peripheral and neural merely? Secondly, what is the relation to the system of the apparent irradiation or diffusion of sensation in tickling, which (apart from one casual reference to secondarily excited sensation) is passed over in silence?

Further, it is evident that, from the point of view of the doctrine of specific energies, the association of a three-fold qualitative continuum with a single set of nerve endings has a certain inconsistency. The appearance of tickle as a phase of the *stichartige* and the *körnige* quality in turn, in its character as an exponent of either *Druck* or *Gefühlsnerven*, offers yet another anomaly. The modification of the conception of tickle which appears in Goldscheider's second monograph was apparently framed in recognition of these difficulties. Whether or not it escapes them is matter for discussion.

According to this later view, the distinction between touch and tickle is not merely a matter of qualitative shading but of degree of objectivation or externalization also. Tickle, which is held to arise simultaneously with contact or touch, and preferably but not invariably with the weaker phases of intensity, is not an independent qualitative co-ordinate of the latter, but something *intrinsic to every touch sensation*, an affective shading, as it were, through which the latter is sensed. As in the sphere

of vision, the less distinctly the outlines of an object emerge, the greater is the prominence of the color in which it is clothed, so in tactual sensation, whatever acts to help or hinder projection and definition acts inversely to suppress or heighten the prominence of the affective shading or tickle.

In the earlier monograph, regional differences of sensitivity were referred to the physiological fact of variation in the *Kitzel-, Tast-, and Schmerzbreite* of the end-organs on different areas; on the specialized tactual surfaces (finger-tips, etc.), the point in the intensity scale at which the quality of tickle passes over into that of touch is very low, on others it is correspondingly high. In the later article, differences in sensitivity are explained on the basis of the use or disuse of the area in question as a perceptive surface, and the fixity or absence of the habit of external reference. Tickle is not simply the sensory effect of the weakest excitation; it is the unprojected, unREFERRED remnant in every tactual sensation. At first glance this would seem to signify that the simplest tactual contents, as such, possesses both an objective and a subjective aspect, the obverse and reverse, so to say, of the same bit of sensation. Frequent association of the sensation with external stimuli develops the objective at the expense of the subjective or tickle aspect; the unprojected tickle remnant (*Kitzelgefühl*) dwindle.

This as it stands is not unintelligible; although, strictly taken, it is not easily translated into the terms of any psychological system. But Goldscheider's actual understanding of the matter seems to be even more intricate. The simplest touch sensation is not only functionally but is also qualitatively two-fold. The split in function runs parallel to a differentiation of contents; tickle is that portion of the contents which never undergoes external reference, the feeling aspect; pressure or touch is the objective or perceptual aspect. With the development of the objective, touch or pressure aspect of the contents, the subjective aspect does not actually dwindle but simply drops into the background, is swamped in the objective. Hence, it is that the feeling of tickle is not absent but is merely in abeyance when tactual surfaces such as the fingertips are lightly stimulated.

This doctrine, taken in detail, is obviously quite as difficult to reconcile with accepted theories of nerve action as was the earlier version. It is, however, highly suggestive, and in the light of further observations a revision of it may be possible.

(b) *Relation to Itch*—A close relation between tickle and itch is noted by certain writers. Goldscheider himself suggests that itching is only some more intensive form of tickle. Von Frey<sup>1</sup> is in favor of identifying the two. He refers them to

<sup>1</sup> *Op. cit.*, 217; and *Beiträge zur Physiologie des Schmerzsinnes, Berichte d. math.-phys. Classe d. kön. säch. Gesellschaft*, 1894, 192.

certain vasomotor reflexes set up by touch and thus explains the delay, lack of exact correspondence with the stimulus intensity, liability to fatigue and disappearance of such sensations when the sense of pressure suffers merely a raising of the limen. This conclusion is based largely upon the exclusion from the category of tickle of the weak punctiform sensations recognized by Goldscheider, but classed by von Frey as indifferent *Berührungsempfindungen*. Von Frey expressly restricts the term tickle to the lively, lasting, irradiating sensations, with strong unpleasant tone and a tendency to awake reflexes, which appear in the train of mechanical excitation.

Richet<sup>1</sup> distinguishes tickle and itch only by the external or internal origin of the initiatory stimulus; at the same time, he maintains the close relationship of tickle and touch. Alrutz<sup>2</sup> has attempted, perhaps, the most extended investigation of tickling, but his results also are biased by a tendency to limit the phenomena under consideration to the semi-painful or itchy phases of tickle. This limitation leads him ultimately to identify tickle with Goldscheider's secondary pain, and to erect out of the two experiences a new sense distinct from primary or pricking pain. The observations which he cites record the results of punctiform stimulation of the cornea, conjunctiva, hard palate, lips, nostrils, and volar surface of the lower arm. Tickle is reported from all these areas, with transitional forms grading into itch from the margins of the lips. The application of a moving stimulus (camel's hair brush) to the lips, forehead, region under the eye, palm and sole of the foot (in the last case a cylinder covered with cotton was used), gave similar results; on the palm the weakest perceptible stimulation gave only touch, and tickle required a slightly higher stimulus intensity. The tongue is also found to respond with tickle when an intermittent stimulus (vibrating fork) is applied. The distinction between deep-seated and superficial tickle (made by Robinson, Sanford and others) is held by Alrutz to be practically non-existent for introspection; the tickle produced by heaviest stimulation of the sole of the foot, apart from the tendency to excite reflexes, differs not at all from the superficial tickle elsewhere.

On the basis of these and other observations, Alrutz concludes that tickle represents a peculiar quality, allied to itching and the secondary pain of Goldscheider. Its distinguishing characteristics, irradiation, diffuseness, indefiniteness and unpleasantness, separate it alike from pressure and pricking pain. For this quality a distinct set of nerve-endings must be posited;

<sup>1</sup> Ch. Richet: *Chatouillement*, Dictionnaire de Physiologie, 1900.

<sup>2</sup> S. Alrutz: *op. cit.*

Thunberg's assumption that the same nerve apparatus, directly or indirectly stimulated, mediates primary and secondary pain in turn is untenable. For this new quality the free intra-epithelial endings present the most likely substrate. The more superficial position and less highly developed structure of these endings explain at once its low limen, inertia, and susceptibility to fatigue.<sup>1</sup>

The following points are offered in support of this hypothesis. (1) Tickling and itching can be obtained only between the pressure points. (2) The limens for tickle, touch, and primary pain are usually different. (3) The latent period for the first is longer. (4) The quality of tickle is nearer that of itch than of pressure, especially in its tendency to irradiation and the production of reflexes; the difference between tickle and itch is mainly one of degree, though the frequent presence of touch sensations with the former usually serves to distinguish them further. (5) Cases are recorded of analgesia without anaesthesia but with loss of tickle. (6) The areas insensitive to tickle and to itch are identical. (7) Areas where pressure and pricking pain are poorly developed possess a strong sensitivity to tickle.

To Alrutz' hypothesis of a specific nerve-energy peculiar to tickle and itch Thunberg<sup>2</sup> opposes the view that these peculiar sensory experiences are completely explicable as modifications of the familiar qualities of cutaneous pressure and pain. Alrutz' evidence on the insensitivity of pressure spots to tickle he regards as insufficient, and explains the 'transitional' forms between tickle and itch as cases of admixture of the two qualities.

(c) *Regional Sensitivity.*—The attempt to correlate the peculiar distribution of tickle sensitivity with sensitivity to pain and pressure, or with the richness of nerve-supply, has been made by various writers. Richet declares that the parts most sensitive to tickle, the soles, palms, nasal and labial mucosa, external passages of the ear, etc., are those richest in the filaments of the "*nerfs tactiles*," while Weber, Bourdon, and others maintain that where the sense of touch is most acute or delicate tickle is feeblest, *e. g.*, on the tips of the tongue, fingers, and nose. Weber, Kiesow and Robinson note the relation of the hairiness of the surface to tickle sensitivity, while Darwin and Hall and Allin seek an explanation in extra-sensory factors,—the infrequency of attack or the vulnerability

<sup>1</sup> Curiously enough, Goldscheider makes these very data the basis for the opposite conclusion, *i. e.*, the association of tickle with the *differentiated* organs of pressure.

<sup>2</sup> Cf. W. A. Nagel's *Handbuch der Physiologie des Menschen*, III, 1903.

of the ticklish areas. The sensitive surfaces enumerated by von Frey, the back, the lines in the palm of the hand, and the folds of skin about the nostrils, are obviously related to secondary pain rather than to tickle.

#### RÉSUMÉ AND CRITICISM

The writers quoted belong, roughly speaking, to the descriptive and experimental types. The former are primarily interested in speculations regarding the anomalies in the affective tone of tickle and the genesis of the laughter reflex. The latter, of whom Goldscheider and Alrutz are almost the only representatives, are concerned mainly with the qualitative relationships and psychophysical substrate of tickle, Goldscheider identifying it with weak pressure, Alrutz incorporating it in a secondary pain sense. While many observations have been collected, and much advance has been made over the original obscure irradiation-hypothesis and the tendency to mistake weakness of stimulus for feebleness of sensation, further introspective study of the relation of tickle to pain, pressure and the like is now in order. Between the observations of Alrutz and Goldscheider there are, as we have already noted, unfortunate discrepancies, and Goldscheider's conception of the two-fold, tickle-pressure aspect of tactful sensation is too ill-defined and hypothetical for unqualified acceptance. In the literature in general a more or less common failure to distinguish between itch, deep-seated tickle, and tickle from a punctiform and moving stimulus, leads to much confusion and contradiction both as to the properties of tickle themselves and as to their interpretation. A further study of the status of tickle as a sense quality, and of its place in the organic or cutaneous continuum, is requisite before any adequate explanation of the peculiar vividness of the tickle consciousness as a whole can be attempted.

#### EXPERIMENTAL

(a) *Peculiarities of tickle to be explained.* The peculiarities by which superficial tickle is set apart from other sensations of the skin appear in the literature above surveyed as follows.

- (1) Qualitative indefiniteness and general intangibility.
- (2) Relative weakness of the adequate stimulus, and disappearance of the sensation with intensified stimulation.
- (3) Susceptibility to fatigue and "excentric anaesthesia."
- (4) Inertia and after-duration of tickle sensations as compared with touch.
- (5) Diffusion or irradiation of sensation to outlying areas.
- (6) Relation to summation, as indicated by intensification of effect with repeated, intermittent or moving stimulus.

(7) Part played by hairs in the intensification or propagation of the effect.

(8) Anomalies in the regional distribution of sensitivity to tickle, which is apparently non-correspondent with the distribution of areas of greatest tactile sensitivity.

(9) Affective tone of tickle, pleasant or unpleasant, and its explanation. Three remaining peculiarities refer especially, though not exclusively, to the deep seated tickle. These are: the disproportionate reflex response to tickle, individual differences in susceptibility, etc., and the relative importance of the "psychic" as compared with the purely sensory in the general phenomenon of tickling.

*(b) Points to be experimentally determined.*

The points most urgently in need of experimental investigation or verification may be formulated as follows.

(1) Is the qualitative contents of tickle in any given instance homogeneous, or a complex of unlike components? Does the peculiarity of the experience reside in the sensation itself, or is it to be referred to the general reflex response, as suggested by Bain?

(2) Are the nerve endings concerned those of pressure, pain, the circulatory system, or some new set; and what is the adequate stimulus intensity? Secondary problems arising here relate to (a) the distribution of tickle points, and (b) the qualitative affinities of tickle.

(3) Is tickle excited directly, reflexly or by central irradiation? Is it simultaneous with touch or delayed?

(4) What is the relationship of superficial and deep-seated tickle; are they qualitatively homogeneous or dissimilar?

(5) What is the distribution of ticklish areas?

*(c) Methods of investigation.*

The following series of experiments was carried on in the laboratory in connection with those on pressure, and with the same observers.

*I. Qualitative analysis of tickle, and determination of the adequate stimulus for punctiform stimulation.* Repeated introspective analysis and comparison of different cases of tickle were undertaken in order to determine the specific quality of the sensation, the possible presence of two or more components (weak pain, pressure, or temperature), and the similarity or difference of the punctiform and moving varieties. A number of areas on the hand, back, arm, and face were examined for the determination of possible qualitative differences. Trial was made of many different modes of stimulation: punctiform stimulation with hairs of varying radii and length, with glass hairs, with a needle; stimulation with a cork point and a camel's hair

brush; successive stimulation with a moving wisp of paper, brush, or bit of cotton; the twitching of the cutaneous hairs; intermittent stimulation with a tuning fork or a bristle attached to a fork; and lastly, the application of a weak faradic current through a blunt or needle-pointed electrode. Paired observations were frequently taken for the comparison of tickle with pain, touch, and contact sensations proper.

*II. Mapping for tickle points.* The regions especially investigated were areas 1 cm. or  $1/2$  cm. square on the palm, back of hand, volar surface of upper and lower arm, outer surface of lower arm, and between the shoulders. The adequate stimulus was found to be a light quick touch with needle, cork point, glass hair, or horse hair. The last proved most serviceable; and a hair set in the von Frey aesthesiometer, variable in length from 2-6 cm., approximately 0.2 mm. in diameter, with a grading of 2.5-8.5 gr/mm. was finally adopted. The conditions most effective for tickle seemed to be those favorable to the setting up of a slight oscillatory or vibratory movement in the skin or underlying parts, with as little liability as possible to damping-off by continuous or heavy pressure. The quick snapping back of hairs was particularly effective, while a slow to and fro movement gave only a sense of touch or pressure. The region immediately about the hairs was found the most sensitive; but, as in the case of granular pressure (see Section A), a small group of points rather than a single point of maximal sensitivity was discovered. This area was rather larger for tickle, corresponding roughly to a circle at whose centre the hair emerges from the skin, whereas pressure sensitivity is usually confined to a small segment to the windward of the hair. On a shaved area, however, the best tickle and the best pressure are usually obtained from the stimulation of the same point, the stump of the hair.

*III. Determination of the place of tickle in graded intensity series.* This experiment was undertaken in order to determine the place of tickle in the intensity series, Goldscheider maintaining and Alrutz denying that it is the first sensation to emerge above the tactal limen. The spots of greatest sensitivity to pressure or contact were located, usually in the close vicinity of the hairs. Each spot was then stimulated with a series of graded intensities; the stimulus hair above described was employed. Qualitative or descriptive judgments were given on each member of the series. As noted in Section A, tickle usually appeared in the lower part of the series but not always at the foot. A stimulus intensity of from 2.5-4 mg/mm. was finally chosen as the most effective for tickle.

*IV. Testing and mapping for tickle with variation of the*

*conditions.* Etherized, cocaineized, and fatigued surfaces were examined, usually with a moving stimulus, in the hope of discovering a disassociation between tickle and touch or tickle and pain. So far as identifying tickle with either pain or contact was concerned, the results were negative. The etherized surfaces showed a loss of brightness for moving tickle and a tendency toward the substitution of a lasting itching quality (probably reflexly excited) for the usual superficial and quickly fading tickle. There was also a dulling or disappearance of contact sensations as distinct from pressure, and of superficial pain, but apparently not of the pain from deeper-lying endings. A scalded surface explored with a light moving stimulus gave all gradations from a sharp tickle to vivid but quickly passing pain, between the normal margin and the point of severest injury.

In connection with the use of cocaine, the discovery was accidentally made that oiling of the skin brings about a reduction of its sensitivity to tickle. Careful mapping of an oiled area indicates that this is less a case of lowering of sensitivity than of the sharper delimitation of the maximal sensitivity spot to the vicinity of the hair. The explanation is apparently this: the reduction of the elasticity of the skin through oiling disturbs the conditions favorable to the propagation or continuance of the slight vibratory movement usually set up by the light setting down and removal of the stimulus hair.

*V. Testing pain and contact points for tickle.* The intermediate bright points noted in Section A were tested for tickle with punctiform and intermittent stimulus (bristle on a vibrating tuning fork), mostly with negative results.

*VI. Regional sensitivity to tickle.* Comparisons were made of adjoining and widely separated areas. The palms of the hands were found to be peculiarly sensitive to punctiform stimulation, the tickle there tending to pass into itch. There is a diminution of sensitivity<sup>1</sup> from the wrist to the shoulder, and the radial and ulnar margins are apparently more sensitive than the intermediate surfaces, and the volar than the dorsal surfaces of the arm. The lips yield a peculiarly poignant tickle throughout a wide range of intensities; the tongue only with the finest of hairs or, better, with a vibrating fork.

#### (d) General Results

*1. Descriptive.* With punctiform stimulation, tickle appears

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<sup>1</sup> 'Sensitivity' as here used refers not to the stimulus limen (which really varies little) but to the vividness of response as tested by a considerable range of intensities, the more insensitive areas refusing to yield a lively tickle except with moving stimulus.

in two forms, of which the first occurs in the vicinity of hair bulbs, on areas such as the arm. It usually comes out immediately, but sometimes only after a brief delay, and is hazily localized on the surface or just below it. It is characterized as "a quick kind of contact," rising abruptly and dying away slowly into a long, cloudy after-image, and is sharp or bright in comparison with an ordinary pressure. It is distinguished from contact by its abrupt rise; its moving, creeping character, which apparently causes it to be felt as a line rather than a point; its indefiniteness; and its liveliness, which is usually accompanied by the desire to rub it away. While tickle ordinarily seems to bear no resemblance to dull or even granular pressure, the observer believes that in quality it is hardly distinguishable from contact or light touch, a weak phase of which is often characterized as "just about to be tickle."

The observers generally agree that the judgment "contact" is constructive, associative, or objective rather than descriptive. It refers to consciousness of area, of locality, or of the nature of the stimulus (which is usually visually imaged), rather than to mere sensation quality, which often eludes recall, and is apparently immediately swamped in the objective judgment. The tickle judgment, on the other hand, usually attends an absence of objective reference, conditioned not so much by the mere quality or faintness of the contents as by its unsteadiness or flickering. *E. g.*, the weakest contact sensation is not necessarily the ticklish one; even with the utmost care and uniformity in the setting down of the stimulus-hair, tickle is not invariably associated with the weakest stimulation, and contact may appear below tickle in the graded intensity series. Further, the tickle judgment seems as much dependent on the sharpness and uneasiness of the immediate contents as upon the reflex shudder, desire to rub or other response which it excites; the tickle judgment is frequently definite when the tendency to such response is practically nil.

The second type of tickle, which perhaps differs from the first only in the matter of intensity and the amount of diffusion of the stimulation, is obtained most characteristically from the lips or the palms of the hands, and is described as quick, sharp, lively, and akin to pain, thrill-like or vibratory, tolerably well localized, with considerable irradiation and after-image. It also is sensed without delay, and the tendency to rub it away, which sometimes appears, seems to be associated mainly with the itching after-image which succeeds.

The tickle accompanying or following a moving stimulus resembles this second type, and is practically the same for the palm and for a hairy surface. It is variously described as phantom-like, feathery, diffuse, of a wavy, pulsating character;

after further practice in observation it is characterized as sharp, bright, intermittent, irradiating, almost tingling, suggestive of a weak, intermittent current, and is localized on the skin or just below it. The possible relationship of tickle to pain is indicated in the faint suggestion of soreness accompanying a swiftly moving stimulus, especially after one or two repetitions, and further in the unpleasant sharpness or liveliness which such a tickle shows on an inflamed or tingling surface, where all gradations from tickle into a closely similar but stinging or "nettly" train of sensations may be obtained. It is possible that this semi-painful character is largely due to reflexly excited after-sensations, into which tickle often indistinguishably merges as it approaches itch; in part, however, it seems a function of the "sharpness" of the immediate tactal contents.

In this tickle of the moving stimulus a second wave of sensation often follows at a just noticeable interval. This after-train may be either a wake of sharp popping points, or a cloudy blur, and is frequently fused either with a faint elusive glow, or with successive waves of cold and warmth. It bears a close resemblance to the gooseflesh shiver, dies away into a dull, superficial tension,<sup>1</sup> and suggests the possibility of a vasomotor reflex affecting either tactal or circulatory endings. This secondary wave is sometimes less, sometimes more ticklish than the primary sensation, grading in some cases into itch. With repetition the tickle of the moving stimulus is at first enhanced (possibly in the after-effect mainly), later greatly dulled, becoming mere contact or pressure, steadier, and indifferent in tone. The brightness of the contact quality suffers at the same time, however; only deep pressure remains unimpaired.

In summary, the observers agree that the peculiarity of the tickle experience is not exhausted by reference to the reflex disturbance excited by it, but resides somehow in its immediate sensory contents. The characteristics common to all forms of tickle are brightness or vividness, inconstancy or unsteadiness (which may be a matter of fluctuations of intensity, or of intermittent, scattering, or successive response of different points), and an ill-defined reference to the epidermis.<sup>2</sup> It is also certain that the weakness of intensity usually predicated of tickle is a matter of stimulus interpretation rather than a direct sensation estimate. The intensity of a light ticklish touch can hardly be equated, psychologically speaking, with anything short of pain, certainly not with the dullish pressure sensations aroused by a considerably heavier pressure on the same area.

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<sup>1</sup> Cf. Section A.

<sup>2</sup> The presence of temperature sensations is apparently non-essential.

The question whether the brightness or sharpness of tickle is to be regarded as a matter of genuine qualitative tinge, of clear-cut temporal or spatial definition, or as a function of attention, conditioned by the intermittence or flickering common to tickle, has been previously touched upon (in Section A). While there seems to be no sufficient reason for distinguishing tickle from contact or surface pressure as a unique quality, the peculiar vividness of the tickle quality remains somewhat perplexing. There seems some ground for identifying this vividness with clearness or the effectiveness of attention. Certain it is that tickle possesses a strong intrinsic claim upon the attention. Nevertheless, the suggestion that the brightness of tickle is merely a matter of exaggerated clearness and definition in attention, and that any lively intermittent tactal sensation would be ticklish, is unsupported by the facts. Intermittent stimulation with the electric current, tuning fork and the like may or may not be ticklish. Observation goes to show that a medium intensity and a medium amount of analysis are optimal; above and below these points we have either a blur, a complex of sharp points, or dull pressure. Whenever the vivacity of the tickle response is dulled by rubbing, fatigue, or the use of weak intensities, when (with electric stimulation) the individual points of sensation are too weak or too rapid for analysis, and when they are too intensive for integration and each in turn stands out in attention, the sense of tickling vanishes. Further observations bearing on this point are as follows. Tickle is most ticklish when just out of the focus of attention, or rather when the whole mass of sensation rather than any one point of it is the object of attention. The quick, tremulous, ticklish contact-sensation from punctiform stimulation of the palm becomes, with a slightly different setting or focussing of the attention, mere indifferent contact. Again, in a long observation period the observer may lose the tickle judgment entirely, apparently as the result of increasing skill and practice in analysis and objective reference.<sup>1</sup>

With regard to the relation of tickle and itch, the observers generally agree in distinguishing the latter as more persistent, painful and intolerable. Its fluctuations in intensity are also more marked.

*2. Distribution of tickle points with reference to the end-organs of pressure.* With punctiform stimulus, the palm alone seems to yield tickle from any point of its surface. Areas on the back of the hand or arm give tickle only in the immediate vicinity

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<sup>1</sup>This disappearance might of course be traced to the wearing-off of reflex excitability, but for reasons which will be clearer later we believe that this is not the whole explanation of the matter.

of hair bulbs. In the intermediate spaces, contact or nothing is felt with the same stimulation. When the hairs are closely shaved, some observers hesitate to give the judgment of tickle except when the stump of the hair itself is touched.

The relation of tickle and pressure points is hardly ambiguous. Tickle may be obtained from any pressure spot if trial is made of different stimulus intensities; from the intermediate pain points very doubtfully even with intermittent stimulation.<sup>1</sup> Further, the points of maximal sensitivity for tickle and pressure agree fairly well, in view of the fact that the position of neither seems to be absolutely fixed,—sensitivity being confined to a minute semi-circle rather than to a point, and shifting with partial fatigue. Alrutz' observations to the contrary, as has been already pointed out, are probably due to the adoption of itch or secondary pain phenomena as the standard of tickle.

*3. Regional sensitivity.* While there are wide variations in vividness, and in the certainty with which the judgment of tickle is rendered, most areas yield tickle with either punctiform or moving stimulation. No absolutely insensitive area, so far as we have investigated, exists, with the exception of certain highly specialized surfaces such as the cornea. Both the tongue and the finger-tips, usually listed as non-ticklish, are found distractingly so if tested with a stimulus of the right intensity, moving or vibratory. What has been called insensitivity seems to be merely a matter of fewness of hairs, infrequency of end-organs, thickness of skin, or position of limen.

With a moving stimulus the following areas gave ordinarily the most vivid tickle: the roof of the mouth; the folds of the skin behind the ears, below the eyes, and between the fingers; the inside of the arm (which was increasingly sensitive toward the wrist); the palm of the hand; and the lips. These surfaces, it may be observed, are characterized either by abundance of fine hairs, or thinness of skin, or the presence of corrugations which may further irregularity and intermittence of sensation. For punctiform stimulation the favorable areas were fewer,—the lips, lower eyelids, cheeks, palm, and outer edge of the forearm giving the surest tickle. These areas apparently have only one feature in common, their richness in Meissner corpuscles or the thickness with which the hairs are set (especially in the case of the cheeks). In general, capillary dilatation seems slightly to increase sensitivity; whatever reduces the elasticity or tension of the skin, as oiling, seems to decrease it.

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<sup>1</sup> The possible participation of these intermediate points of sensitivity in the tickle of a moving stimulus is another matter.

*(e) Conclusions as to the Histological Substrate of Tickle.*

1. *Summary of peculiarities.* No good reason is forthcoming for divorcing tickle from the sense of touch or superficial pressure. The practical identity of the points of maximal sensitivity of the two, the appearance of tickle without delay in an enormous number of cases, and the parallel effects of fatigue or over-stimulation on tickle and contact, furnish direct evidence of their close relationship. Indirect evidence of equal weight is furnished by the introspective verification of the qualitative similarity of the two sensations, based upon our analysis and study of granular pressure in Section A.

Tickle is characterized by its intangibility and absence of clear objective reference. The explanation of this peculiarity must be sought elsewhere than in its nearness to the limen, and its consequent qualitative indefiniteness and inability to call up assimilatory ideas. Tickle is not invariably correlated with the feeblest tactal impression; the latter is often sensed as contact, while tickle appears only at a higher point in the intensity scale. Further factors to be accounted for in any theory are the vividness, unsteadiness, and apparent diffusiveness or irradiating character of the simplest punctiform tickle.

2. *Hypothetical.* The inconstant wavering character of moving tickle, and the sense of motion which accompanies even the weakest tickle arising from punctiform stimulation, suggest that the uniqueness of tickle lies less in any qualitative peculiarity than in the irregular temporal course of the sensation, and its consequent grip upon the attention. The physiological conditions of this intermittence or unsteadiness must then be sought. In the case of the tickle attending a moving stimulus, the swift appearance and disappearance of successive points of sensation, combined on hairy areas with the effect of the vibratory response of the elastic hairs, may account fairly well for the phenomenon. Again, in the case of the ticklish halo surrounding a core of contact or coming out after the removal of the stimulus, explanation may have recourse to the irregular response or ringing off of different endings. The spread of stimulation to adjacent end-organs is especially possible with a light quick stimulus, which may form the starting point of a series of tiny ripples.

The query concerning the minute tickle, unattended by contact, which proceeds from punctiform stimulation of the skin, must next be answered. Does this also involve the response of more than one nerve-ending or nerve organ? In the case of the palm, where the tactile corpuscles are thickly set, it is doubtful whether with the utmost caution and the use of the finest point the isolated stimulation of a pressure organ is pos-

sible; multiple response may account, in part at least, for the vivid tickle which results. The tickle following punctiform stimulation of a hair-bulb on the arm, when the skin has been oiled and softened to prevent the transmission of the stimulation to the adjacent endings, obviously represents a case for which some other explanatory factor must be sought.

Either the actual physical vibration of the tissues, or some as yet unexplained oscillatory condition within the end-organ itself, or an intermittent internal stimulation attending direct or reflexly excited alterations of the pressure conditions within the capillaries of the skin, would here serve the purposes of explanation. It is worthy of note, in this connection, that an intrinsically oscillatory character was attributed by Meissner to his "contact" sense, and later claimed by von Frey for the sense of pressure. Goldscheider's similar view (proposed in his earlier monograph) we have already noted: intermittence is a normal function of the conditions within the end-organ, especially with light stimulation; a faint stimulus produces a whole series of excitations or vibrations, which are either damped off or transformed to an uniform steady displacement when a heavier continuous pressure is substituted for a light touch. The fact, however, that tickle is not invariably the outcome of the weakest touch stimulation, that for any pressure organ the adequate tickle stimulus is sometimes liminal, sometimes decidedly supraliminal, shows the need of a more careful examination of the conditions.

Our study of the granular pressure sensation furnishes us with a certain cue. If a more or less intensive stimulation of a single pressure organ may give rise to a pressure sensation not in itself quite simple, it is highly probable that the tickle produced by a slight disturbance of the same end-organ will be also in a fashion complex. Indeed, our conclusion was that both tickle and the sensory response to a weak intermittent current represent disintegrations of the 'granular pressure sensation,' which only render its compound structure more obvious. Accepting the Meissner corpuscles and the hair follicles as the end-organs of touch (and of tickle), we have in the number of endings furnished to a single organ and the possibility of their successive or asynchronous excitation an immediate histological basis for irregularity or unsteadiness of sensation. Further, the fact that the irregularity of response from these endings, which is sensed as tickle, is the customary but not the invariable result of light stimulation is readily intelligible. The stimulus may be insufficient (in area or intensity) to produce the general disturbance of the endings which gives rise to tickle; the fluctuations may be below the flicker limen. Or, when a penetrating or sharply pointed stimulus is applied above a hair

follicle, it is conceivable that one or more endings only are affected directly, and that little commotion is produced in the organ as a whole; the resulting sensation would then be identified as contact.

This asynchronous response may also be made to account for the apparent irradiation or diffusion of a simple tickle sensation (apart from the cases of actual gooseflesh response). The unsteadiness of the tickle of punctiform stimulation is easily confused with the intermittence of sensation which is ordinarily associated with the movement of an object along the surface of the skin. Since an intermittent stationary stimulus is rare in experience, and the difference in local sign for minute distances is slight, an interpretation in terms of movement frequently follows tickle, and an illusory judgment of irradiation or diffusion is given.

The origin of the tickle after-image, which is sometimes a mere breath-like phantom, sometimes vivid and bordering on itch, remains to be considered. With the exception of the possible addition of a painful factor in itch, it is in all ways similar to the primary tactful tickle just described. Whether it is to be traced to circulatory endings, to indirect excitation of the end-organ of touch through reflexly aroused vaso- or pilo-motor changes, or to mere inertia of the original tickle sensation, must remain a matter for speculation.

Although the above suggestions as to the mechanism by which a simple touch may be given an oscillatory character are impossible of verification, the fact that intermittence or irregularity, however produced, is an essential in tickle finds sufficient evidence in our introspections. The significance of this factor in the explanation of the tickle consciousness as a whole is further apparent in the supplementary introspections on ticklishness and tickling which follow.

#### *(f) Supplementary Introspections*

*Deep-seated tickle.* The following casual observations on deep-seated tickle go to show that here also a just perceptible unsteadiness or intermittence is the important feature. If a light swift friction of the surface of the arm is repeated until the bright superficial tickle has worn off, a deeper, dullish, unsteady and uncomfortable feeling succeeds, accompanied by an almost irresistible impulse to shudder or draw away. If a ridged surface, such as the finger-tip or the sole of the foot, is similarly treated, the effect is even more striking. The deeper tickle produced by heavy chest massage is similar, of an uncanny and uneasy character, and seems to represent not a solid mass of sensation but a loosely woven tissue in which the individual elements are barely distinguishable. In general, the

deeper tickle is dull as compared with the more superficial; at the same time it contains a certain element of soreness or sharpness. This deeper tickle is closely similar to the vaguely ticklish after-image which sometimes follows the heavy or continued stimulation of a single hair-bulb. The latter sensation is dull and of a vague uncertain character, due apparently to the unsteadiness which is a common feature of all tickle.

The peculiar liveliness of the reflexes excited by deep-seated tickle is probably due, not only to the customary exaggeration of dynamogenic values by discontinuous stimulation, but also to the greater number of nerve endings affected by massive kneading or rubbing. The discontinuity or unsteadiness is rendered more obvious by successive intensifications of the sensation when the stimulus passes over the ribs or the ridges on the soles of the feet or the palms of the hands.

*Affective Reaction and Reflexes.* The pleasantness and unpleasantness of tickle seem to be less a function of its immediate sensory aspect than of the muscle response which it excites and the suggestions aroused by the stimulus, and are largely dependent on the mental or nervous state of the individual. The pleasantness of the tickle in the ribs may be, in part at least, merely a suggestion from the smiling set of the facial muscles reflexly excited along with the more general muscle contractions; the pleasantness of a more superficial tickle is probably due to its light touch component and the soothing organic response and general relaxation conditioned by it. The unpleasantness of deep-seated tickle can usually be traced to the violent contraction of the diaphragm and adjacent muscles and the accompanying compression of the internal organs. The unpleasantness of cutaneous tickle is probably due partly to the sharpness of the sensations, which are almost akin to pain, largely to the vague, uneasy suggestion of the unknown, which gives an uncanny tinge to tickle as to the gooseflesh shiver. On the whole, the subjective moment in the immediate sensation of tickle is best described neither as pleasantness nor as unpleasantness, but as excitement. The significance of this statement we shall examine later.

(g) *Final definition of tickle.* We have cited already various facts which indicate that the definition of tickle is not complete when its constituent elements have been described and classified and their intermittence emphasized. Tickle is something more than a complex of intermittent or oscillatory sensations. The fact that intermittent stimulation with tuning fork, interrupted current, or moving touch is not always ticklish indicates that tickle is a function of certain rates and intensities only. Too slow a rate and too high an intensity are alike unfavorable, and apparently for the same reason; they

facilitate analysis, and the complex tends to fall apart into individual points, each capable of definite localization and objective reference. Further, the sense of tickle comes out most strongly when the initiatory sensations are, so to speak, just in indirect vision, and the attention is dispersed over the immediate sense-contents and the general bodily reaction. When a single sensory component or an assimilatory idea gets the focus of attention, and consciousness becomes analytical or critical, the tickle judgment vanishes. While the sense of tickle is heightened by the direction of the attention away from the idea of the stimulus to the sense-contents, the judgment of tickle is instable, often disappearing at a certain stage of practice in the analysis of this contents. Tickle is then replaced by the perception of contact.

This instability of the tickle judgment indicates that tickle is better defined as a complex of intermittent sensations *at a certain point of fusion or amalgamation*. The favorable conditions are those in which the tendencies to analysis and amalgamation are equally balanced, and we have neither a disconnected series of sensations nor a smooth union. Below the point of adequate fusion, which is dependent upon the rapidity and intensity of the component sensations and on the direction and skillfulness of the attention, we have disconnected sensations, either indifferent or verging on the painful, and capable of individual projection; above it we have complete fusion or steadiness, interpreted as contact and given objective reference, *i. e.*, a perception. — This conclusion finds corroboration in the following introspective data. The two criteria, aside from the affective tone and tendency to reflex withdrawal, by which the observer finally came to distinguish between tickle and the weakest contact, were as follows: (a) lack of steadiness, smoothness, unity, and definite punctiform localization; and (b) absence of reference to a stimulus, and of visualization of a definite surface, or of the descent of the stimulus.

The significance of the structural pattern above assigned to tickle becomes fully apparent only when the tickle consciousness is examined as a whole, in relation to experience in general and in comparison with other typical complexes, perception in particular. In so examining it we come first upon certain characteristics to which so far we have done scant justice, its vividness, its characteristic feeling-tone, and its power to excite a general muscular reaction. The latter feature, which has given rise to so much speculation is, no doubt, in part to be explained by reference to a familiar physiological fact, the greater effectiveness of intermittent stimulation in exciting reflex centres to action. Further, this motor reaction is, to a certain extent, self-propagating, since certain of the sensations

to which it gives rise, especially those arising from the goose-flesh shiver, and the activity of the plain muscle fibres in the skin, supplement the tickle sensations proper and prolong the motive to general muscular reaction. The reinforcement which the motor reaction thus lends to the tickle sensations proper is probably part of the secret of the hold which tickle has upon the attention. Physiologically and psychologically, perhaps, we might say that the motor accompaniment of tickle and the hold of the latter upon the attention are both functions of the unsteady, fluctuating character of its components; biologically, they may be interpreted as expressions of the significance of movement in the earlier phases of the racial history. The motor reaction in general may be regarded as representing a survival either of specific reflexes associated with the primitive protective functions of the once all-important sense of contact, or of a primitive type of neural mechanism in general, in which excitations were guided directly into channels of motor discharge rather than of perceptual functioning.

This motor reaction may, however, be further interpreted as standing in a certain fixed relation of dependence to the peculiar structural pattern and degree of amalgamation of the contents which is known as tickle. This is indicated in the facts above cited, that the motor and organic reaction disappears, along with the observer's sense of tickle, when consciousness becomes critical, analytic and perceptual. This circumstance, which might be set up as an evidence of the dependence of the sense of tickle on motor reaction, we should interpret as follows. So long as attention is incompetent to cope with the semi-amalgamated series of impressions which constitutes tickle, this contents functions as a whole, the primitive sensorimotor path of least resistance is followed, and we get the reflex shudder and incipient innervation of the appropriate muscles of withdrawal or laughter, effective in proportion to the cumulative force of the stimuli and the motor excitability of the individual. When, however, analysis of the contents into its individual components is effected, the energy otherwise overflowing directly into motor channels is expended in the excitation of the sensory or ideational centres, and the assimilatory ideas and images, visual, verbal or motor, push the immediate sense-contents out of the centre of consciousness, the muscular reaction is largely effaced, and the 'perception' of certain definite sensations of contact succeeds the 'feeling' of tickle. Tickle is tickle only so long as it can monopolize the field of attention, in the form of an unsteady mass of sensation with which analysis is unable fully to cope.

'Feeling,' in the sense in which it is here employed, denotes, of course, neither an ultimate affective element, nor the un-

analyzable and unlocalizable, in the usage of Kroner, Lagerborg and others. As here used it refers merely to that peculiar type of consciousness which, in terms of function and cognition, represents not so much the abstract physiological properties of the process experienced as its physiological effect on the organism as a whole. In structural terms, it is simply that mass of ill-localized, ill-analyzed sensation which, because of its cohesion and its persistence, exercises an intrinsic claim upon the attention, and is distinguished by its peculiar vividness and its strong dynamogenic value. Tickle, as we have already said, while never actually indifferent, is best described neither as pleasant nor as unpleasant, but as exciting. In so speaking we have no reference to a third affective element; the tickle experience is, in fact, not so much exciting as it is itself (a certain form of) the 'feeling' of excitement.

It is in this connection especially that the true relation of tickle to organic sensation becomes apparent. The classification of tickle with the *Gemeinempfindungen* by Weber, Wundt and others has already been noted. While we have decided against the strictly organic character of tickle, its status as 'feeling' at once allies it to the internal sensations, since these customarily enter into feeling-combinations rather than into objective perceptions. From such organic complexes as hunger, disgust, excitement, and the like, tickle differs mainly in its greater accessibility to analysis, and hence in its greater tendency to disintegration.

While the basis of our classification of tickle with the bodily feelings is not precisely that of the older writers, the difference lies mainly in greater explicitness and in the attempt to formulate the difference in more distinctively psychological terms. The old division of experience into the objective and subjective was philosophical and schematic rather than psychological. In Weber's terminology, the use of the terms unprojected and projected sensation is strongly suggestive of the distinction between mere sensation and intuition or concept in the system of Kant. The peculiarity of the latter is not a matter simply of the addition of centrally excited ideas, assimilative or associative, but rather of some mysterious transformation which the contents undergoes at the hands of the understanding. The fact that in perception sensations are referred to the external world, in feeling to oneself, contains in itself no *a priori* reason why they should be differently sensed. Again, Wundt's reference to the external or internal character of the stimulus, and the lack of exact correlation between the course of stimulus and sensation when the stimulus is internal, expresses only very remotely the actual basis of the differentiation of contents. The internal origin of a sensation is undoubtedly a drawback

to its clear perception, mainly on account of the limited opportunity it offers for the simultaneous experiencing of the same physical fact through the medium of other senses, and the consequent failure to set up associations which might serve as an aid both in analyzing it out from other contents and in orientating it as a perception in consciousness. Tickle, however, fails of analysis and projection not from the lack of external associations at its command, but because of a lack of unity, and a baffling swiftness and irregularity with which the processes of perception cannot keep pace. In addition, the kinæsthetic or organic sensations to which it gives rise tend to assimilate it to themselves, and thus weaken the motive to analysis and bind it the more firmly to the subjective.

The lack of objective reference is, then, rather an effect than a condition of the peculiar character of tickle as a 'feeling'; a condition merely in so far as it means the non-appearance of certain centrally excited sensations which would help to break down the tickle complex; an effect, in that the temporal, spatial, and intensive irregularities which constitute tickle a semi-cohesion of shifting sensations, with the status and magnified motor value of a 'feeling', are precisely the factors which stand in the way of its objective reference or projection.

Tickle may thus be finally defined as an intensely vivid complex of unsteady, ill-localized and ill-analyzed sensation, with attention distributed over the immediate sensory contents and the concomitant sensations reflexly evoked. Its immediate sensory contents is not qualitatively different from contact, but in actual experience tickle is distinguishable from the ordinary contact complex in its character of a 'feeling' rather than a perception.